LECTURE NOTES

ON

AIR TRANSPORTATION SYSTEMS

B.Tech V Semester

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UNIT-I

AVIATION INDUSTRY

INTRODUCTION

In a short span of 100 years, we have gone from making a few test flights to orbiting celestial bodies, from sliding along sand dunes to spanning oceans, from performing feats of isolated daring to depending on aviation in our everyday lives. Speeds have increased a thousand-fold, as have altitude and range capability. No longer is the sky the limit. Ahead lie risks and rewards as vast as space itself. We have the promise of new airliners that fly with greater fuel efficiency, of huge air freighters that move the nation 's goods, of an expanding general aviation fleet, and of the peaceful uses of space for exploration and research.

THE AEROSPACE INDUSTRY

The aerospace industry includes those firms engaged in research, development, and manufacture of all of the following: aerospace systems, including manned and unmanned aircraft; missiles, spacelaunch vehicles, and spacecraft; propulsion, guidance, and control units for all of the foregoing; and a variety of airborne and ground-based equipment essential to the testing, operation, and maintenance of flight vehicles. Virtually all of the major firms in the aerospace industry are members of the Aerospace Industries Association (AIA) or the General Aviation Manufacturers Association (GAMA). Founded in 1919 and based in Washington, D.C., the AIA is a trade association representing the nation's manufacturers of commercial, military, and business aircraft, helicopters, aircraft engines, missiles, spacecraft, and related components and equipment. GAMA, also based in Washington, D.C., is the trade association that represents the interests of manufacturers of light aircraft and component parts. As the 21st century began, approximately twothirds of the aerospace industry's output was bought by the federal government. During the past two decades, this figure has ranged as high as 74 percent. At the same time, the aerospace industry is the world's largest producer of civil aircraft and equipment. Roughly 6 out of every 10 transports operating with the world's civil airlines are of U.S. manufacture, and in addition, the industry turns out several thousand civil helicopters and general aviation planes yearly. These facts underline the unique status of the aerospace industry. Its role as principal developer and producer of defence, space, and other government required systems in large measure dictates the industry's size, structure, and product line. Because it operates under federal government procurement policies and practices, the industry is subject to controls markedly different from those of the commercial marketplace. But the aerospace industry is also a commercial entity, and it must compete in the civil market for economic and human resources with other industries less featured by government constraints. Its dual nature as government and commercial supplier makes the aerospace industry particularly important to the national interest. Its technological capabilities influence national security, foreign policy, the space program, and other national goals. Also, the efficacy of the national air transportation system depends to considerable degree on the quality and performance of equipment produced for the airlines and the airways operators. Naturally, such an industry is vital to the U.S. economy, especially in the following areas:

1.**Trade balance**. The excellence of U.S. aerospace products has created strong demand abroad, with theresult that the industry consistently records a large international trade surplus.

2.Employment. Despite several years of decline in number of workers, the aerospaceindustry remains one of the nation 's largest manufacturing employers.

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3. Research and development. The industry conducts more research and development (R & D) than any other industry, and R & D is a major long-term determinant of national economic growth.

Impact on other industries. A great many new aerospace-related products and processes have spun off from the initial aerospace requirement and have provided value to other industries, both in sales and in productive efficiency. In addition, the aerospace industry is a large-scale user of other industries' goods and services: it has been estimated that for every100 aerospace jobs created, another 73 are created in other industries. Each of these factors represents a significant contribution to the U.S. economy; collectively, they elevate aerospaceto a key position among the nation's major industries.

Characteristics of the Industry

The history of the aerospace industry has been a saga of continuing adjustment to changing national policy and economic conditions. Since 1960, fluctuating government demands and avariety of international events have teamed up to produce a roller -coaster like sales curve: upto a peak, down to a valley. Over the years, the industry 's operations have become increasingly complex, with each increment of complexity heightening the industry 's problems in adapting to change. Today, the industry 's unique characteristics make the,adaptive process extraordinarily difficult. An understanding of the difficulties is best promoted by an explanation of how the industry has been transformed in the past quarter of a century.

Prior to 1950, the industry was relatively unsophisticated. Its product line was entirely aeronautical aircraft, engines, propellers, avionic components, and accessories. Long run production of many airplane types was the order of the day. The labor force, during the post-World War II retrenchment period, was less than one-fifth of the later peak. Three -fourths of the workers were moderately skilled production workers. R & D was an essential prelude to production, but the subsonic aircraft then being built were less demanding of technological advance, and R & D represented a considerably less significant portion of the total workload than it does today.

The transformation began in the early 1950s with the production of the jet- powered supersonic military airplane, which brought about across-the-board changes in the industry new types of engines, totally different airframes, different on-board equipment, new tooling and facilities, and, most of all, a vastly greater degree of complexity in products and the methods employed in producing them. New-airplane performance dictated that far greater emphasis be placed on R & D. The combination of R & D and product complexity required a major shift in the composition of the work force to include ever-increasing numbers of scientists, engineers, and highly skilled technicians. All of these changes resulted in increased emphasis on an ever more sophisticated managerial process.

While the industry was adjusting to these changes, it inherited a new responsibility: development and production of guided missiles, particularly long-range ballistic weapons. Then came another major change: the application of turbine power to commercial airliners, whose resemblance to military jets ended with their propulsion systems. The need to transport large numbers of people at high subsonic speeds and multi mile altitudes involved a further modification of the industry 's methods. Finally, in the late 1950s, the industry was assignedstill another responsibility: fabrication of equipment to meet the nation's goals in space exploration.

Each of these changes compounded the need for change in the entire industry—more R & D, greater product complexity, more personnel per unit produced, higher skill levels in the work force, longer program development time, and greater need for new facilities with only single-program utility because of their specialized natures. Such changes contributed to higher costs of the end products, and the demand in the 1960s and 1970s for still more advanced aerospace systems further escalated both

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the rate of change and the costs. In defence output, cost—together with the greater capability of the individual system influenced a trend away from volume production and toward tailored manufacture of fewer types of weapons and fewer numbers of each type.

A half- century of evolution has let the aerospace industry with a set of characteristics unique in U.S. manufacturing:

- 1. Performance demands for new systems require continual advancement of the technological frontier, which in turn involves unusual degrees of uncertainty and risk.
- 2. Because the government is the principal customer, the product line is subject to revisions in program levels occasioned by changing requirements and funding availability.
- 3. Equipment that challenges the state of the art is necessarily costly, the more so because requirements generally dictate short production runs, negating the economies of large-scale production.
- 4. Technologically demanding programs require personnel emphasis in the higher skill levels. Hence, labor input per unit of output is substantially larger than in other manufacturing industries.
- 5. The combination of technological uncertainty and long lead times, open 7–10 years and frequently longer, between program initiation and completion, makes advance estimation of costs particularly difficult.
- 6. Because there are few customers and relatively few programs, competition for the available business is intense.
- 7. All of these characteristics contribute to exceptional demand for industry capital, yet profits as a percentage of sales are consistently well below the average for all manufacturing industries.

Economic Profile of the Industry

The aerospace industry is composed of about 60 major firms operating some 1,000 facilities, backed by thousands of subcontractors, vendors, and suppliers. The principal product line aircraft, missiles, space systems and related engines, and parts and equipment is characterized by high performance and high reliability, and hence high technology and high unit value. Activity, as measured by sales volume, focuses on aircraft, both civil and military, which account for almost 55 percent of the industry's workload. Missile systems represent about 6 percent of the total, and space fabrication for about 21 percent. In addition, 17 percent comes from related products and services, which embrace the industry's growing efforts to transfer to the non-aerospace sector some of the technology developed in aerospace endeavors. Sales in 2005 amounted to \$170 billion, broken down as follows: aircraft, \$89.1 billion; missiles, \$15.3 billion; space-related materials, \$37.3 billion; and related products and services, \$28.3 billion. Related products and services include all non-aircraft, non-space vehicle, and non-missile products and services produced or performed by those companies or establishments whose principal business is the development or production of aircraft engines, missile and spacecraft engines, missiles, or spacecraft early 1990s were difficult for U.S. aerospace companies. Declining defense spendingand a protracted airline recession caused U.S. aerospace sales to plummet, resulting in the industry's worst downturn in 40 years. By 1996, the industry began to turn around (see Table 1-1). The 8 percent rise between 1995 and 1996 was largely attributable to increased sales of civil aircraft, engines, and parts. Sales of missiles have steadily increased for the years 2000–2005. This category should increase in the years ahead as the war on terrorism continues around the globe. Changes in aerospace product sales are driven by the dynamics of the industry 's customer base. During the 1980s, the Cold War environment set the tone for increased U.S. defiance spending, and aerospace companies responded accordingly. In 1987, industry sales to the Department of Defense (DOD) accounted for 56 percent of total aerospace business. Yet federal spending priorities have gradually changed. The end of the Cold War and pressures to balance the federal budget led to spending cuts in

defense programs. Aerospace sales to theDOD fell substantially between 1987 and 1999 (Table 1-2). There was a slight rise in defense spending in 2000 and 2001, largely as a result of the nation's war on terrorism following thetragedy of September 11, 2001. Higher procurement spending occurred in 2002 and beyond as the global war on terrorism continued.

Although DOD purchases continued to slide during the beer part of the 1990s, the demand for commercial transports increased significantly with the resurgent economy and the return to profitability by the airline industry. General aviation sales also increased following passage of the General Aviation Revitalization Act in 1994. Both the airline and general aviation sectors were significantly affected by the slowdown in the economy starting in 2000 and continuing through 2002.

The aerospace industry represents one of the nation 's largest employers, with approximately 625,000 workers on the rolls at the end of 2005. Combined with multiplier effects on other industries, it is estimated that the aerospace industry accounts directly or indirectly for close to 2 million U.S. jobs.

A labour-intensive industry, aerospace employs as many salaried as production workers, the highest such ratio among comparable industries. The emphasis on high-tech R & D in the aerospace industry demands a greater number of scientists, engineers, and technicians than are utilized by most industries. At its peak, the aerospace industry employed almost 30 percent of all U.S. scientists and engineers engaged in R & D. The figure has still averaged a relatively high 15 percent for the past 20 years or so.Testifying to the excellence of U.S. aerospace products is the strong performance of the industry on the international market. The industry has a significant impact on the U.S. balance of trade. Back in 1967, aerospace exports reached the \$2-billion-a-year level, and in succeeding years, they rose sharply, mainly because of deliveries abroad of advanced technologycommercial jetliners. In 1973, the industry set an all-time export record of more than \$5 billion, and in 1974, that figure increased by almost \$2 billion. In 1981, there was another substantial increase, to a new record of \$17.6 billion, and in 1986, the figure rose to \$19.7 billion, which represented 9.6 percent of total U.S. exports. In 2005, exports topped \$65 billion. At the same time, aerospace imports have traditionally amounted to only a fraction of the value of goods exported. Thus, aerospace has consistently shown a substantial trade surplus.

Industry Suppliers

Aerospace products perform very sophisticated functions and are complex and costly to manufacture. Because of this, aerospace companies do not attempt to design and assemble finished products entirely in-house. Instead, companies specialize and, where appropriate, contract work out to other companies. A major aircraft manufacturer may use over 15,000 suppliers in its transport manufacturing activities.

It should be noted that aerospace suppliers are predominantly U.S. companies. In fact, data from 2005 indicate that imports of aircraft parts, engines, and engine parts amounted to \$27.8 million or approximately only 19 percent of total U.S. aerospace sales. In the case of Boeing, less than 4 percent of its supplier base is located overseas, and the foreign content of its commercial jets averages 13 percent. In short, aerospace helps drive the domestic economy.

Naturally, the largest amount of economic activity involved in the assembly of aerospace products occurs among aerospace companies themselves. One aerospace firm may be responsible for the design, assembly, systems integration, and final testing of a product, such as an aircraft. That company subcontracts work to other aerospace manufacturers, who supply aircraft wings, tails, and engines. These relationships vary from program to program, with companies exchanging roles as prime

contractor and subcontractor. The most recent figures suggest that this interchange, or intra-industry trade, accounts for approximately 34 percent of aerospace purchasing activity.

In addition, much of the aerospace sector's impact on the U.S. economy arises from the industry's position as a major consumer of goods and services supplied by firms outsideofaerospace. These services include legal assistance, advertising, accounting, and data processing activities. Other service industries that are prominent aerospace suppliers include wholesale and retail trade, finance, and insurance.

The importance and value content of electronic components in aerospace end products have grown significantly in recent years. Items such as antennas, electronic connectors, and liquid crystal displays are included within this commodity category. Their growing share of the value of aerospace systems and vehicles is due principally to two factors. First, electronic component costs are being driven upward by Pentagon demands for state-of the- art technology. This demand, coupled with the short production runs inherent in most military programs, has increased technology unit costs. Second, in an attempt to restrain militaryspending, the DOD has postponed new product acquisitions and instead has been upgrading existing weapons systems with improved avionics. The costs of electroniccomponents are clearly rising relative to those of other inputs. Other important commodities purchased by the aerospace industry include primary, nonferrous metals (for example, copper, aluminum, lead); radio, TV, and communications equipment; and scientific and controlling instruments.

The Government Market

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Despite growing percentages of nongovernment and non-aerospace business, industry activity sstill dominated by government contracts with the DOD and the National Aeronautics and Space Administration (NASA), a factor that has important effects on the industry's economicstatus. Preliminary sales figures for 2006 indicate that approximately \$93 billion of the total sales were to these two government agencies (see Table 1-2).

Defense Contractors the optimism that followed the breakup of the former Soviet Unionwas replaced by the reality of the Persian Gulf War in 1991 and what it signified: continued regional threats from various corners of the world. Fast on the war's heels came the conflictin the Balkans and an understanding that peace was equally threatened by European regional and ethnic tensions. Nonetheless, the military arsenals of the major powers clearly were too large once the possibility of conflict between the United States and the former Soviet Union was greatly diminished. The process of adjusting to the post-Cold War era is still under way. The defense forces of the United States, its Western allies, and those of the former Soviet bloc nations are declining in size, nuclear arsenals are being dismantled, and the defense industrial bases of major Cold War players are shrinking and consolidating. Leading up to the catastrophic events of 9/11, defense companies experienced decreases in business as a result of dwindling government contracts. Companies cut costs by trimming personnel at all levels. In the United States, aerospace sales to the DOD declined from a high of \$61.8 billion in 1987 to \$47.6 billion in 2001. Total employment fell from 1.3 million in 1987 to an estimated 794,000 at year-end 2000, largely as a result of defense cutbacks. Military aircraft-related jobs declined from 656,000 in 1986 to 459,000 by yearend 2000. Despite the drops in business, defense companies impacted by a lesser number of contracts overcame the challenge of keeping key technical teams in place to maintain the technology capabilities on which the chances for future contracts rest. In 2006, business has picked up as a result of continued terrorism threats and political instability in the Middle East. Companies are also focusing on improving their design and manufacturing processes and procedures, such as concurrent engineering and inventory control, to enhance productivity and competitiveness. They are restructuring by eliminating less profitable lines

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of business and adding new capabilities. Many companies are striving for greater balance between defence and commercial work, while others concentrate on the core defense business in which they are strongThe industry continued its consolidation throughout the 1990s. The merger of Martin Mariea and GE Aerospace made Martin Marie the largest defence electronics company in the world until the mid-1990s, when Lockheed purchased Martin. Lockheed went on topurchase the tactical aircraft business from General Dynamics, which significantly strengthened that company's position as a leading producer of fighter aircraft. The purchase by Hughes Aircraft of the missile division from General Dynamics enabled Hughes to move into a joint lead with Raytheon in missile production and sales until Raytheon acquired Hughes's missile division. In 1998 Texas Instruments became a part of Raytheon. Later, Boeing acquired the Hughes satellite division. Other major acquisitions were the purchase by Loral of LTV's missile division and by the Carlyle Group and Northrop of LTV's aircraft division.

In addition to consolidation in the defence sector, some companies with existing civil and military product mixes are taking steps to expand their nondefense activities or to move into related areas. Boeing is allocating resources to its new 777 transport program. Raytheon purchased the corporate jet unit of British Aerospace to expand its commercial aircraft business. Textron purchased General Dynamics' Cessna Aircraft Company. But these were only the most sizable and newsworthy of many mergers and acquisitions as aerospace and related business divisions switched hands.U.S. companies teamed up to perform R & D and to bid on government work. They are seeing up joint ventures and other arrangements (sometimes including foreign partners) to apply technology developed for military purposes to commercial aerospace and non aerospace markets. The anticipated growth of the civil aircraft business invites the application of technology to commercial avionics, air traffic control systems, and aircraft maintenance and upgrades. Other civil business opportunities being sought include highway traffic management, the potential electric car market, hazardous waste and weapons disposal, high-speed data transmission, environmental sensing, space satellite communications, law enforcement (aircraft surveillance, --smart computer-linked police cars, bio sensing of drugs and bomb-making chemicals), large-screen television and home TV satellite service, software conversion, factory automation, light-rail systems, and cellular telephone systems. Although the range of new business is extensive, it will take time to develop markets. The amount of new business will not totally offset lost defence procurement dollars for years to come, if at all.As companies deal with financial pressures, a smaller market, and uncertainty about DOD acquisitions, not surprisingly, R & D spending is down, as is capital investment, with few exceptions.

With the end of the procurement budget decline not yet in sight, defence contractors are more dependent on a balanced government–industry sharing of the work performed in government laboratories and service maintenance depots. Military exports are also more important both as a share of total defence sales and as an aid to preserving the technology and production base that keeps down the cost of defence systems for U.S. taxpayers. *NASA*. The days of the Apollo program, when annual real increases in U.S. government space spending were the norm, are long past. The *Challenger* space shuttle disaster of January 28, 1986, and reduced spending on discretionary programs resulted in greater congressional scrutiny of civil space budgets. In addition, space efforts have been tempered by the diminished competition from the Russian space program and the end of the ideological competition between the leading capitalist and the major communist nations. The loss of the Space Shuttle *Columbia* on February 1, 2003, has led to further examination of space spending.

Yet many U.S. policymakers also recognize the importance of space from a technical, environmental, and commercial standpoint. As defence programs shed skilled workers, ahealthy space sector is viewed as a mechanism that can reabsorb some of the talent that becomes available. In addition, the commercial segment of the industry, particularly telecommunications, has been a growth area in an

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otherwise troubled aerospace market. Environmental problems are receiving greater attention today, and the ability to monitor global warming, ozone depletion, and climatic changes from space is a valuable capability. A variety of space platforms are needed to meet these needs. The cumulative effect of these opposing forces is a NASA budget that, while not declining, is also not showing any signs of real growth. Since 1990, NASA spending has been flat. In addition, some funds that once were earmarked for space programs will instead be shi_ed into aeronautical projects; the space station program will experience the greatest cutbacks. Consequently, U.S. government funding for civil space activities is not expected to rise significantly any time soon. Companies remaining in this business will have to be very skilful at selecting which space programs will demonstrate returns within a zero-growth NASA budget. This situation may prompt U.S. companies to seek foreign opportunities with greater vigour.

The Civil Aviation Market

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The United States traditionally has been the largest market outside of the former Soviet Union for commercial transports, helicopters, and general aviation aircraft. Close ties between U.S. manufacturers and their domestic customers have provided U.S. aerospace companies with a solid sales base. Although the domestic market will remain vital to U.S. aircraft programs, the economies of scale necessary for success in today's commercial market compel manufacturers to take aninternational approach. This is due to the fact that an enormous amount of capital is required to cover the development and tooling costs associated with a new program. For example, the cost of launching a commercial transport program today is approximately \$5 billion.Manufacturers must wait about four years before deliveries begin and revenue is generated from their initial investments. Compared to other industries, the customer base for commercial passenger jets is limited and the volume of orders is low. Generally, between 400 and 600 aircraft must be sold before a program reaches the break-even point. These market characteristics also apply to other civil aircraft manufacturing sectors. Consequently, every sale is important in order to pay back the nonrecurring costs of R & D and production tooling and to make a profit. This is why exports are an integral part of the product and marketing strategies of civil aircraft companies. Since 1990, foreign sales have accounted for over 70 percent of commercial transport and civil helicopter sales and about 40 percent of general aviation aircraft sales. Total civil aerospace exports reached more than \$55 billion in 2005. Civil aircraft manufacturers have had a global view for some time, as their export figures indicate, but recent changes in market conditions have increased the need for them to remain committed to an international strategy.

Air Transport. The principal civil aviation product is the airline transport. The traditional and obvious difficulty in this area is the fact that sales depend on the financial health of another industry the world's airlines. The need for new jetliners is evident. The world transport fleets aging, and the older, less efficient aircraft must be replaced. After reaching a high of 589 units in 1991, the number of shipments declined precipitously during the early 1990s as the economy went into recession and the airlines lost \$13 billion during the first four years. The economy rebounded by the mid-1990s, and the orders poured in as the airline industry returned to profitability. The number of transport aircraft shipments reached a peak of 620 in 1999, when the industry recorded record profits. Once again, the economy slowed down in 2000 and fell into recession in 2001. The tragedy of September 11, 2001, exacerbated the decline, and the carriers lost \$7.7 billion for the year. Transport aircraft shipments followed the decline during the first few years of the 21st century (see Table 1-3).Before World War II, more than two dozen companies were in the business of designing and building large commercial airlinerslarge at that time meaning 20 seats or more almost all for airlines in their home countries. Today, the number of prime manufacturers of large airlinersand that now means 100-plus seatsis down to two: Boeing and Airbus. In 1997, Boeing proposed a merger with McDonnell-Douglas for an

estimated \$14 billion. Although the proposed merger drew severe criticism from Airbus, it was approved.

The winnowing-out in this industry has happened for many reasons, the chief one being the cost of developing new aircraft. As one generation of aircraft has succeeded another, the costs of building the latest aircraft and designing its successor have risen exponentially. Combined with the uncertainties of the marketplace, the spiraling cost of development and early production of new aircraft has made the commercial aircraft business a risky venture.

Since deregulation in the late 1970s, the trend has been toward less and less differentiation within the airline industry as the airlines have competed more and more on the basis of price and schedule and as some of the oldest and proudest names in the industry have disappeared through merger or bankruptcy. In making their purchasing decisions, the airlines, in turn, have increasingly focused on a single factor: which of the various aircraft available to them in a few distinct categories is the low - cost solution to the task of carrying a certain number of passengers a certain distance? Each of the two major competitors strives to enter new markets ahead of the other by developing new and more cost-efficient aircraft, and each one tries to defend its markets in the absence of any natural barriers on the strength of being the low-cost producer.

Boeing has been able to maintain approximately 60 percent of the market for large jet transports in an increasingly competitive global market. The company's commercial transportproducts include the 737, 747, 757, and 767 models; the latest, the 777, entered service in 1995. Boeing's most formidable competitor has been and will continue to be Airbus Industries. Airbus launched its first aircraft, the A300, just 30 years ago. By 1995, Airbus had captured approximately 30 percent of the worldwide market for commercial jet transports. Airbus's goal is to increase further its market share in the United States and abroad; the company's latest design, the 555-seat A380, which made its first flight in 2005, aims to see that this goal is reached.

Extensive levels of government subsidization by France, Germany, the United Kingdom, and Spain have enabled Airbus to develop a full family of aircraft without ever having made a profit, to price these aircraft without full cost recovery, and to offer concessionary financing terms to customers. Boeing and McDonnell- Douglas objected strenuously to this practice, claiming unfair competition. Airbus, in turn, claimed that Boeing and McDonnell-Douglas benefited over the years from the large military contracts that have offset a large part of their R & D expenses. In fact, the United States has long had a defence budget double that of Western Europe, with a large investment in military aircraft R & D and long production lines. While both Boeing and Airbus were able to offer customers a full range of jetliners, McDonnell-Douglas was unable to. With a limited product range, McDonnell-Douglas dropped from being number two in the commercial aircraft marketplace in the late 1970s, with more than a 20 percent share of the total world backlog, to number three in 1995, with less than a 10 percent share. McDonnell-Douglas was subsequently purchased by Boeing.

The cost of developing new airplanes has become staggering. Every time a company like Boeing moves forward with a new program, it is essentially putting its entire net worth on the line. Enormous front-end investments must be made for a return that will not be realized until many years later—if at all. Boeing's program to develop and manufacture the 350-seat 777airplane provided a good example of the enormity of the challenge. The company spent billions to develop the new airplane, which involves several thousand suppliers and over 800,000 different parts.As Airbus and Boeing continue to compete, they are forced to develop new products and services that are attractive to an existing and

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potential customer base. Both manufacturers aregoing head-to-head on development of new aircraft technology that will revolutionize the future of air transportation. Airbus is launching the A350 in response to Boeing's B787 Dream liner. Both aircraft are being developed with twin-engines capable of flying 250 to 300 passengers on long distance routes at costs much less than today's modern aircraft. Bothaircraft will be light in weight consisting of composite materials amounting to significant decreases in fuel costs. Although the cost of developing new airplanes is enormous, the cost of not moving ahead is even greater. A company's ability to maintain its position as a global aerospace manufacturer depends fundamentally on its capitalizing on new market opportunities. In instances in which the market is limited or the barriers to entry are prohibitively high for one company, international collaboration may be the wave of the future.

Although U.S. aerospace companies have dominated the global market for many years, the use of overseas suppliers of components and subassemblies is increasing. There is nothing strange about that, because two-thirds of the world market for large airliners exists outside the United States. Though companies in countries such as Italy and Spain have been major suppliers for many years, the nations of Asia and the Pacific Rim collectively have been distinctly minor suppliers. That is bound to change, for two reasons: those same countries already account for a substantial portion of the world market for commercial airliners (20 percent and growing rapidly), and they plainly have both the desire and the capability to participate in the production of new aircraft. Unquestionably, international collaboration is a key strategy in the broader effort to remain competitive in the aerospace industry. Joint programs in which the partners share costs offer a means of generating the requisite capital for advanced commercial airplane and engine development in the face of high and rising costs. They also give the U.S. companies involved access to foreign markets that might otherwise be denied to them in view of the trend toward directed procurement. Offsetting these advantages to some extent is the fact that joint U.S.-foreign ventures inevitably strengthen the technological capabilities of foreign industry. In short, sharing American know-how might prove costly in the long run, because it further enhances the competitive posture of foreign companies. But sharing, it should be remembered, is a two-way street.

Factors Affecting Commercial Transport Sales

Continued market leadership of U.S. aircraft manufacturers is closely tied to the existence of healthy, profitable U.S. airlines. The huge size of the U.S. domestic market has beenimportant to U.S. manufacturers by providing them with the broad base of demand necessary to launch new aircraft programs. Traditionally, over 40 percent of commercial jets on orderfrom U.S. manufacturers have been delivered to U.S. airlines. These aircraft make up one-third of the value of the manufacturers backlog of unfilled orders. Large order volumes helpmanufacturers spread costs over a larger production run, which allows them to reduce their unit costs and be more competitive. Now more than ever, as they seek the export sales crucial to market leadership, manufacturers need the foundation of a strong U.S. sales base.

By the end of 1993, the airline industry was in a tailspin. Passenger and freight traffic was stagnant, aircraft by the hundreds had been placed in storage, industry losses and debts were mounting, and aircraft orders were being cancelled. The downturn had also spread to the commercial transport sector, and aircraft manufacturers were forced to scale back production and lay off thousands of workers. By 1997, however, the airline industry was taking off. Air traffic and profits were back up and net orders for U.S. transports jumped from 256 in 1995 to 620 in 1999. The pace of these recovery commercial aircraft producers struggling to keep up. Civil aviation has a history of cycles, and with the slowdown of the economy in 2000 shipments began to tumble. Aircraft companies are implementing programs to reduce these market swings. Also, some economists are suggesting that

business cycles in general should be less severe due to factors such as deregulation and global competition. Nevertheless, several factors strongly influence cycles in the air transport industry.

Economic Growth. Economic growth has a tremendous impact on the civil aviation market. It is important because it broadly influences the demand for air transportation services, which, in turn, affects aircraft orders and deliveries. During periods of economic growth, companies build and service new outlets, which lead to an increase in business travel. In addition, family incomes generally rise, which results in greater spending on leisure travel. Yet, the reverse is also true: when economic output falls, businesses close facilities, unemployment rises, and air traffic declines.

The correlation between economic growth and air travel has been recognized by analysts for many years. A generally accepted rule of thumb holds that there is a 2.5–3 percent increase in world air traffic for every 1 percent increase in world economic growth.

Inflation. Inflation is important because it influences economic growth. When prices arestable, interest rates tend to be low, and this encourages investment and business expansion. When prices rise quickly, interest rates also climb. Eventually, high interest rates will inhibit economic activity, which can put a damper on air traffic. Because high interest rates raise the cost of borrowing, they can also make aircraft financing prohibitive. In addition, inflation can result in escalating labor and fuel costs. When this happens, airlines are faced with the unpleasant choice of either absorbing those higher costs or raising their fares.Inflation has grounded the airline industry on more than one occasion. In 1970, 1973, 1978, and 1991, air carriers faced rising fuel and labor costs. During those same years, inflation also plunged the major world economies into a recession, causing air traffic and airline profits to decline.During the recent recessionary periods (1990–1994 and 2000–2002), air carriers sustained huge losses. Airlines have attempted to control their costs and have made it clear to aircraft manufacturers that they want the price of planes to come down. Aircraft companies have reduced their prices through implementation of long-term programs aimed at cutting costs and improving efficiencies, efforts that should benefit airlines well into the future.

Fleet Capacity. The passenger load factor is used to measure airline capacity utilization. Theindicator is expressed as a percentage, relating the number of passengers flown to available seats. When load factors are low, airlines have more excess capacity than when load factors are high. High load factors and rising air traffic place airlines under pressure to buy aircraft. If load factors are rising during a business cycle, this also suggests that airline revenues are improving. This is important if airlines are planning to order aircraft because it enhances their ability to purchase or lease planes.

The passenger load factor for world airlines raised during the latter half of the 1990s, and orders for new aircraft reached record levels. Unfortunately, as was the case in previous economic downturns, air traffic declined in the early 2000s and load factors fell, prompting the air carriers to reduce fleet capacity and cancel orders. By year -end 2006, load factors were at normal levels and in some cases higher than ever.

Replacement Aircraft. Airlines order aircraft to increase their capacity; they also purchasenew transports to replace their older, less efficient models. The advancing age of current fleets suggests that replacement orders should be on the rise through the mid to late 2000s. In a related issue, the airlines were required to meet low stage 3 noise levels in the United States by December 31, 1999; the date in Europe was April 1, 2002. Although many of the over 3,000 aircraft have been grounded, modified using engine hush kits, or sold outside the United States and Europe, there is still a significant pent-up demand for replacement aircraft.

Airline Profitability. Commercial transports are expensive assets: smaller models start atapproximately \$25 million and jumbo jets cost over \$140 million. To make these types of purchases, air carriers need to raise capital in the financial markets, and therefore, they need to demonstrate to potential investors that their operations are profitable. After losing billions of dollars in the early 1990s, the airlines returned to profitable operations in the latter half of the decade. Airline stocks were soaring and optimism prevailed as the carriers entered the new century. The economy slowed down in the spring of 2000 and went into recession in 2001, followed by the tragedy of September 11, 2001. Once again, the carriers experienced record losses in 2001 and 2002. US Airways filed for bankruptcy, and other major carriers were not faring much better. Massive employee furloughs took place during these years. United won \$5.8 billion in wage and benefit concessions from its employees to stave off bankruptcy. By the end of 2002 the industry was in shambles. Over 90 percent of the passengers were flying on discount fares and low-cost carriers were eating away at market share from the old-line airlines.

With no retained earnings and stock prices at record lows, the carriers'only source of funds in the foreseeable future appears to be the debt market. This will not be an easy task because the carriers are already faced with a substantial debt load from the last round of aircraft purchases.

A Cyclical Industry. The civil aviation market is cyclical. This is important to recognize tofully understand the environment surrounding transport orders and deliveries. Since 1971, orders for U.S. transports have peaked five different times, and the average period between a trough and a peak has been three years. The delivery picture shows a similar pattern. World transport deliveries have peaked six different times since 1960. When deliveries have fallen, the declines have been steep (drops average over 50 percent); nevertheless, deliveries have continued to rise over the long term. These cycles are set in motion by the underlying forces of economic growth and recession and are further magnified by the nature of aircraft manufacturing.

In the retail industry, items often sit on store shelves for weeks before they are sold, and buyers usually can take their purchases home the day they are bought. But aircraft are too expensive to build and then keep in inventory. Instead, they are manufactured only after an order is placed. This creates a time lag between order and delivery dates that can last well over a year.

Also, in the retail industry, there are many suppliers. If a customer has to wait for delivery from one supplier, that customer can go to another vendor offering a more immediate response. But again, the aircraft industry is different. Building a commercial transport takes an enormous investment, limiting the number of manufacturers in the business. If the order line for aircraft fills up, customers have little recourse but to wait. If aircraft demand rises, manufacturers will initiate a new program or increase their production rates. Unfortunately, due to the tooling and supplier links that must be set up and the bottlenecks that can develop among strategically important suppliers, reaching full implementation takes time. For example, it took Boeing two years to double its production rate for all models.

These situations can create an imbalance between demand and supply that causes orders and deliveries to swing abruptly. Yet there is also a behavioral side to these cycles. Airlines and aircraft leasing company's worry that they might miss a market upturn if they are placed near the end of an ordering line. At the first sign of a market turnaround, they frequently scramble en masse to place orders. This creates a surge in orders that can push back delivery dates even further. As a result, air carriers near the end of the line might, in fact, receive their deliveries years later, as air traffic is subsiding. These deliveries then create an overcapacity problem, causing aircraft orders to swing downward. Manufacturers who had just invested in greater production capability now find themselves with excess capacity, and a shutdown reverberates through the industry.

IARE	AIR TRANSPORTATION SYSTEMS		
	Source from Air Transportation Systems by Mike Hirst		

These cycles are disruptive, and aircraft manufacturers are working to minimize them. Companies have launched efforts to shorten the product development phase and reduce the time gap between aircraft order and delivery. This is being accomplished by adapting computer-aided design and manufacturing technologies that obviate the need to build mock-ups. To improve program communication and efficiency, manufacturers are using concurrent engineering, which involves establishing teams of design, development, production, and sales people at the beginning of a program. Prime contractors are strengthening their relationships with their suppliers and increasing the two-way flow of technology. Boeing, specifically, is overhauling its production and systems software to simplify the way it tracks and handles millions of parts. Boeing also has reached agreements with American, Delta, and Continental that will provide those airlines with greater flexibility for ordering aircraft over a 20-year period.

Future Trends in Air Transport. The air transport sector has shown a strong tendency torecover from each downturn with renewed vigor. Economic growth and low inflation have been the key factors that have fed the demand for air transportation. This has pushed aircraft utilization to record levels, improved airline profits, and fueled programs to replace older aircraft. Together, these factors have contributed to a rise in aircraft orders. Nevertheless, civil aviation has a history of cycles, and we can expect that orders and deliveries will fall.

Transport deliveries have been rising for the past 40 years. This suggests that deliveries will continue to climb in the future. In fact, transport manufacturers and analysts alike project that deliveries will almost double over the next two decades. The key assumption here is that the international economy will continue to grow.

General Aviation

After record shipments of 17,817 units in 1978, the general aviation segment of the aerospace industry, which manufactures light aircraft and components, experienced a 16-year downward slide in sales. After reaching a low of 928 units shipped in 1994, industry shipments increased for the remainder of the decade and through the years 2000 and 2001 (see Table 1-3). Historically, the economic cycle of the general aviation industry closely paralleled that of the national economy. This relationship changed during the 1980s and early 1990s. High aircraft prices, interest rates, operating expenses, and product liability costs all contributed to the downward cycle. Other analysts cited changing life-styles, tax laws, and foreign competition as further reasons for the sluggish sales performance of recent years.

The general aviation industry has undergone deep and broad structural changes. The major independent manufacturers have been taken over by conglomerates. Textron acquired Cessna from General Dynamics, and Beech is now Raytheon, taking the name of its parent company. Piper emerged from bankruptcy and is now operating as the New Piper Aircraft Corporation. While Raytheon and Cessna continue to concentrate on producing multi-engine and jet equipment, Cessna resumed production of several single engine models in 1996 era 10-year hiatus. This was largely in response to passage of the General Aviation Revitalization Act of 1994, which limited product liability suits involving older aircraft.

Business use of light aircraft remained strong despite the economic downturn in the 1980s, for several reasons. Small aircraft are fuel-efficient. In fact, they use less fuel per seat- mile than any other form of air transportation. A Boeing 747 gets 40.7 seat -miles per gallon of fuel (mpg); a six-passenger Piper Lance gets 89.4 mpg, the six-seat Beech Bonanza 86.4 mpg, and the seven- seat Cessna 207 84

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	Source from Air Transportation Systems by Mike Hirst	

mpg. Even light twin-engine aircraft perform in terms of fuel usage than the extremely efficient Boeing 777. Furthermore, airlines require considerable ground support facilities, such as tugs, shuttle buses, baggage trucks, and heated and air- conditioned offices and terminals, most of which use petroleum- based energy. Rarely is a major airline terminal as close to a person's ultimate destination as is a general aviation airport. Private-use aircraft can fly straight to their destinations, whereas airlines frequently use indirect routes with one or more stops along the way. This has been particularly true in recent years with the establishment of hub airports by the major carriers.

The efficient use of time is another reason general aviation will expand. As our energy problems deepen and the airlines seek to make more efficient use of costly fuel, it will be increasingly difficult to reach many locations via scheduled carriers. Only those routes that generate high load factors will continue to be viable, which means that the trend will be toward decreased airline service. Fewer than 5 percent of the nation's airports have airlineservice now, and the majority of flights serve only 30 major centers. It often is not possible using the airlines to travel in one day between such cities as New York and Lexington, Kentucky; Chicago and Charleston, West Virginia; or San Francisco and Salem, Oregon. In the future, general aviation will be the only time-effective means of travel between many of the places business-people need to go.

The upward turn in units shipped and particularly dollar volume has ushered in a new wave of optimism to the general aviation sector. Unquestionably, general aviation is here to stay, but as in the air transport segment, manufacturers will continue to experience ups and downs with changes in the economic cycle, just as they have in the past. To satisfy the need for public transportation, there will be considerable growth in the third-level, or commuter/regional, airlines, those operators who offer scheduled service in larger general aviation and short-haul transport aircraft. Commuter/regional carriers will link a number of small cities with low passenger volumes as the larger carriers concentrate their services in the high-density markets.

Helicopters. Sales of U.S.-manufactured civil helicopters continued to fall during the early 1990s(see Table 1-3). The helicopter industry's trade balance, positive through the 1980s, was negative through the early 1990s. (It should be noted that much of U.S. manufacturer Bell Helicopter's production is based in Canada and thus is not counted as a U.S. export when shipped abroad.) Today, lightweight, single-engine models dominate U.S. rotorcraft_ shipments, while French/German-owned Euro copter is the largest manufacturer of larger, more expensive models. Overall, foreign manufacturers should continue to increase their share of the total world market even as U.S. manufacturers gain ground, as evidenced by the upturn in shipments since 1996.

Related products and Services

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Technology is simply knowledge, and it has a high degree of transferability: the know- how acquired in exploring aerospace frontiers can be put to work to provide new products and services of a non-aerospace nature, with resultant benefits to the economy as a whole. For many years, the aerospace industry has pursued a program of technology transfer in an effort to make broader use of its wealth of know-how. The transfer process has been hampered by the lack of an aggregated market such as that provided by the federal government or the airlines in aerospace work. In non-aerospace activity, the industry has operated largely on a single-project, single -location basis, working with individual federal, state, and local government agencies and other customers to transfer technology in such areas as medical instrumentation, hospital management, mass transportation, public safety, environmental protection, and energy. Despite the lack of an aggregated market, the results have been impressive in terms of industry sales volume, particularly in most recent years. In 1973, sales for related products and services topped \$3 billion; but by 2005, they had reached approximately \$28 billion

THE AIR TRANSPORTATION INDUSTRY

The air transportation industry includes all civil flying performed by certificated air carriers and general aviation. Because this industry is the major focus of this text, it is important to define exactly what we mean by the terms certificated air carriers and general aviation.

The Civil Aeronautics Act of 1938 defined and established various classifications within aviation:

- 1. Air carrier means any citizen of the United States who undertakes to engage in air transportation.
- 2. Air transportationmeans interstate transportation.
- 3. Interstate air transportation the carriage by aircraft of persons or property as a common carrier for compensation or hire.
- 4. No air carrier shall engage in any air transportation unless there is in force a certificate issued by the Civil Aeronautics Board authorizing such air carrier to engage in such transportations.
- 5. Reading these sections of the act together, one sees the airline business as defined by Congress. The key words are italicized: common carrier and compensation or hire. Therefore, the appropriate term for airlines is not commercial airlines, but certificated (common) air carriers. Having legally defined air carrier aviation, the act went on to define other types of aviation in a second category in the following way: Air commerce means interstate ... commerce or any operation or navigation of aircraft within the limits of any Federal airway or any operation or navigation of aircraft which directly affects, or which may endanger safety in interstate air commerce.
- 6. Interstate air commerce mean the carriage by aircraft of a person or property for compensation or hire or the operation or navigation of aircraft in the conduct or furtherance of a business or vocation, in commerce between any State and any other State
- 7. The first paragraph, which is all-inclusive and embraces all non-air carrier aviation, defines general aviation as we know it: non- commercial or private use. That paragraph is modified by the second one quoted, which goes on to define two subparts of general aviation:
 - a) Business aviation, where the aircraft is used in the conduct or furtherance.
 - b) Business or vocation, andCommercial aviation, where people are carried for compensation or hire, but not as a common carrier notes that those words are omitted. Today, general aviation is commonly described as all civil aviation except that which is carried out by the certificated airlines. His segment of the industry will be covered in detail in Chapter 4, The General Aviation Industry. Chapter 5 provides an in-depth review of the airline industry.

Contribution to the Economy

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Over the past 60 years, the air transportation industry has become an increasingly important part of the U.S. economy. Aviation is the nation's dominant intercity mode of transportationfor those passengers and goods that must be transported quickly and efficiently. It has become so universal that no one questions aviation's importance as an essential form of transport. Aviation employs many thousands of people, and thousands more work in aviation's support industries, such as hotels, restaurants, rental cars, real estate, construction, andmanufacturing. Individuals in these industries benefit economically from aviation regardless of whether they actually fly. Aviation 's final products are passengers and cargo safely and efficiently delivered to their destination. In 2004, U.S. airlines carried 698 million passengers and registered 28 billion ton-miles of cargo on approximately 9 million scheduled

AIR TRANSPORTATION	SYSTEMS
Source from Air Transportation Sy	stems by Mike Hirst

departures. U.S. airlines also carried more than 11 million passengers and over 6 billion ton- miles of cargo on approximately 400,000 non-scheduled departures. Although scheduled airlines provide service to about 800 communities, over 5,000 communities of all sizes can access the air transportation system via publicly owned general aviation airports, including non-scheduled, ondemand, and charter flights. The industry estimates that more than 160 million passengers are carried annually aboard general aviation aircraft and trends indicate this statistic is to increase over the next decade.Most people are familiar with the aviation elements that they see and useairports, airlines, and general aviation aircraft. They also might be familiar with some of the support elements baggage services, travel agents, and others. However, the aviation industry is much more than that; it includes an intricate set of suppliers of a wide variety of goods and services, all of which benefit economically from aviation. With economic deregulation of airlines in the late 1970s, air cargo networks were able to facilitate just-in time shipping, providing expanded services at lower costs. Optimization of just-intime shipping allows short production and development cycle times and eliminates excessive inventory in the logistics chain, regardless of facility location. Without the availability of ubiquitous, reliable, efficient air express service, U.S. businesses would be unable to realize the competitive economies of just-in-time production. Air transportation offers many cost advantages-lower lead times, quicker customer response times, improved flexibility, and reduced inventory. Many high-tech, high-value industries have embraced air transport for its time and cost advantages in manufacturing and distribution and because it improves delivery reliability by providing time-definite guarantees.

One-stop shopping has become extremely important to businesses in their selection of logistics service providers and air cargo carriers. The ability to use a carrier that will provide door-to-door service with single -vendor control makes the entire logistics chain much less complicated than the traditional method of using several providers with different delivery functions. The major integrated carriers provide seamless trucking, warehousing, and distribution service functions in addition to air cargo. As a consequence, shippers are increasingly substituting blended air and surface transportation services provided by (or through) a single carrier.

In July 2002, DRI -WEFA Incorporated in collaboration with The Campbell-Hill Aviation Group completed a study titled *The National Economic Impact of Civil Aviation*. As of early 2006, this is the most recent study. Using 2000 data, the study examined the impact of civil aviation, which included:

- 1. Scheduled and unscheduled commercial passenger and cargo operations (including cargo-only transportation)
- 2. General aviation (including business aviation and air taxi operations)
- 3. Their related manufacturers, servicing, and support (including pilot and maintenance technician training)
- 4. Their supply chains (indirect impacts)
- 5. The effects of income generated (induced impacts) directly and indirectly by civil aviation
- 6. The direct, indirect, and induced impacts of related industries, such as travel and tourism, for which air transportation provides an enabling function

Economic Impact Types and Causes. The aviation industry economic impacts calculated in the DRI-WEFA study included those financial transactions that could be traced to aviation and that were of value to the nation's economy and its citizens. The impacts were real andquantifiable; hypothetical, imaginary, or subjective impacts were not considered in the study. The impacts were divided into three types: direct impacts, indirect impacts, and induced impacts (see Table 1-4).

Direct impacts were those financial transactions linked to the provision of air passenger and air cargo services and the provision of aircraft. They typically occur at airports and aircraft manufacturing firms and include expenditures by airlines, airport tenants, air cargo firms, Fixed-Base Operators (FBOs), ground transport firms, flight schools, airport concessions, aircraft manufacturers, and others.

The direct impact in 2000 was \$343.7 billion and 4.2 million jobs in civil aviation or in industries related to civil aviation, such as travel and tourism. Civil aviation, excluding related industries, directly produced \$183.3 billion in GDP (\$169.6 billion from commercial aviation and \$13.7 billion from general aviation) and 2.2 million jobs.

Indirect impacts were those financial transactions linked to the use of aviation. They include expenditures by travelers who arrive by air, travel agents, business aviation, and others. Indirect impacts typically (but not always) occur at off-airport locations. The indirectimpact amounted to \$254.9 billion and 3.2 million jobs arising indirectly in the other industries in the supply chain to civil aviation and related industries. —Induced impacts were the —multiplier implications associated with direct and indirect impacts.

The DRI-WEFA study confirmed that virtually all activities involved in the provision and use of aviation are important to the nation 's economy. The total economic impact of civil aviation, including its —multiplier effect, was calculated as \$903.5 billion for 2000, or 9.2 percent of GDP. Civil aviation including related industries represented 11.2 million jobs.

Commercial aviation accounted for 88 percent of aviation 's total impact. Although general aviation accounted for only 12 percent of the total, it generated nearly 1.3 million jobs and \$102.0 billion in economic activity.

Contribution to Efficient Conduct of Business

Air transportation is now as much a part of our way of life as the telephone or the computer. Speed, efficiency, comfort, safety, economythese are the symbols of both modern society and modern air transportation. If you need to get somewhere in hurry, and most businesses do, because time means money, then flycomfortably, safely, and economically.

Air transportation has enabled employees of business and government organizations to reach any point in the world within hours, whether flying by air carrier or a general aviation aircraft. Certain values are associated with this timeliness:

- 1. Quicker on-the-spot decisions and action
- 2. Less fatigue associated with travel
- 3. Greater mobility and usefulness of trained, experienced executives, engineers, technicians, troubleshooters, and sales personnel
- 4. Decentralized production and distribution
- 5. The ability to expand market areas through more efficient use of management and sales personnel

To visualize a world without modern air transportation, consider the world of 1940, when surface transportation was still in its prime and air transportation was in its infancy. The 800-mile New York–Chicago trip took 17 hours each way on the fastest rail routing. The same trip today can be made in a couple of hours. Also consider the thousands of smallercommunities now served by business representatives flying in and out the same day it took days and weeks to cover the same territory back in the 1940s.

IARE	AIR TRANSPORTATION SYSTEMS
	Source from Air Transportation Systems by Mike Hirst

ImpactonPersonalandPleasureTravelPatterns

In 1940, few people had ever flown in a scheduled airliner. By 1960, one-third of U.S. adults had flown; by 1981, two-thirds of the population over 18 years of age had been airline passengers, and by 2006, over 85 percent of the adult population had flown on a commercial flight. The impact of the air age on personal and pleasure travel has been at least as great as it has been on business travel. And airline fares remain a bargain compared to the priceincreases of other products and services over the past 50 years. The combination of speed and economy has altered people 's ideas about personal travel. In 1940, only a few wealthy individuals travelled to places like Florida or Hawaii, much less to Europe. Today, thousands of college students fly to Europe during the summer. Entire regions have developed into strong tourist-oriented centers because air transportation has made them accessible to vacationers from many areas. The economic development of such areas as Florida, Hawaii, Puerto Rico, Las Vegas, Phoenix, and San Diego can be attributed to the access provided by air transportation.

1.2 H I S T O R I C A L P E R S P E C T I V E

In 1914, most of the world was too preoccupied with World War I to notice that for a fare of \$5 (more if the passenger weighed over 200 pounds); a person could buy a ticket for a one-way trip in an opencockpit Banjoist flying boat that flew across Tampa Bay, connecting Tampa and St. Petersburg. The land journey took an entire day; the flight took about 20 minutes. On January 1, 1914, the mayor of St. Petersburg became the first passenger on a regularly scheduled airline using heavier-than-air aircraft in the United States. Financed by P. E. Fansler and flown by Tony Janus, this primitive operation folded after four months when it ran into financial trouble. A humble beginning for the now-giant industry. Between 1912 and 1916, the Post Office Department made several a Tempts to obtain federal appropriations for the transportation of mail by air, but no appropriations were granted until 1916. In that year, Congress made funds available for the establishment of proposed air mail routes, several inAlaska and one between New Bedford, Massachuse and Pawtucket, Rhode Island. ThePost Office Department issued ads inviting bids on the routes, but no bids were forthcoming because of the lack of planes suitable for the services.

The development of large bombing planes during World War I demonstrated that the airplane could be used for fast commercial and mail transportation. In 1918, Congress appropriated \$100,000 to the Post Office Department for the development of an experimental air mail service and for the purchase, operation, and maintenance by the Post Office. Department of what were referred to as aero planes thus were born the air transportationindustry.

THE FORMATIVE PERIOD: 1918–1938

After preliminary studies, the first regular air mail route in the United States, 218 miles in length, was established on May-15, 1918, between New York City and Washington, D.C. One round trip was made every day except Sunday, and an intermediate stop in Philadelphia enabled the receipt and discharge of mail and the servicing of the planes.

The service was conducted jointly by the United States War Department and the Post Office Department. The War Department furnished the planes and pilots and performed the operation and maintenance, and the Post Office Department amended to the sorting of the mail, its transport to and from the airport, and the loading and discharge of the planes.

IARE	AIR TRANSPORTATION SYSTEMS
	Source from Air Transportation Systems by Mike Hirst

This joint arrangement continued until August 12, 1918, when the Post Office Department assumed exclusive responsibility for the development of a larger-scale mail service.

The New York–Washington air mail route was discontinued on May 31, 1921, because of the need for economy and the failure of Congress to specifically authorize the route.

The Post Office Department Service

When the Post Office Department took over the entire air mail service in 1918, including personnel and equipment and the complete operation and maintenance of the domestic air mail service, it shouldered a formidable task. This period in the history of the air mail service represented a trial stage during which the Post Office Department experimented with airplane equipment, weather service, night flying, flying and ground service arrangements, routes, postage rates, and other areas in which additional data were Required before the service could be placed on a sound basis and operated nationwide over regular routes. Initially, the Post Office Department acquired a number of airplanes from the War and Navy Departments, rebuilding or remodeling the planes to transport mail. Safety and carrying capacity were the principal qualities sought when selecting or remodelling the planes. Later, the Post Office Department acquired planes especially designed for carrying mail. The success of the first experimental route led to the extension of the service through the establishment of a transcontinental route between New York City and San Francisco.

Weather conditions were one of the most serious difficulties faced in establishing the air mail service. The Weather Bureau of the Department of Agriculture was enlisted to provide the pilots with adequate weather information. Improvements were made in the design of planes, in airplane motors, and in airway marking and communication facilities, which made it possible to operate the air mail service in weather that would have prevented flying in the early years of the service.

One of the many contributions of the Post Office Department to the development of aviation during this period of experimentation and development was the demonstration of the practicability of regular night flying over regular routes on fixed schedules. In 1923, using data compiled by the War Department, the Post Office Department studied the feasibility of regular night flying. Army planes had done a considerable amount of night flying during the war. In addition, airplanes had been flown at night occasionally before these experiments, but regularly scheduled route flying had not been exempted.

A lighted airway was established between Cheyenne, Wyoming, and Chicago, and emergency landing fields were located along the airway and equipped with lights. Pilots made experimental night flights over the routes. In August 1923, a regular schedule of night flying was established between Chicago and Cheyenne, and in July 1924, regular night service was established on the transcontinental route.

Other Post Office Department air mail routes were added or discontinued as need for the routes was demonstrated or the lack of need became apparent. One of the most important routes, the overnight service between New York and Chicago, was established on a regular schedule of five nights a week in 1925 and on a nightly basis in 1926.

The Post Office Department experimented with various types of airplanes in actual flight conditions during this period. At first, planes that could be acquired by the government at nominal prices were used in air mail service. Later, the steady increase in volume of mail traffic necessitated the development of a type of plane capable of carrying more than 500 pounds. The government accepted

competitive bids, and the Post Office Department began purchasing mail planes that were faster and that had twice the mail-carrying capacity of the earlier types.

By 1925, domestic air mail service in the United States had progressed to the point that the feasibility of regular service had been adequately demonstrated. Facilities for air transportation had been established, and the desirability of continued direct government operation or private operation under contract with the government was widely discussed. The U.S. government traditionally had arranged with railroads, steamship lines, and other carriers for the long-distance transportation of mail, with the Post Office Department providing the services incident to the collection, sorting, local transportation, and delivery of the mail.

Contract Mail Service

The third stage in the development of air mail service was ushered in by the Contract

Air Mail Act of 1925, the so-called Kelly Act, named after its sponsor, Clyde Kelly (see the section Federal Legislation and the Airlines). The Kelly Act authorized the postmaster general to enter into contracts with private citizens or companies for the transportation of mail by air. Shortly thereafter, the joint congressional commiĴee on civil aviation, which had been established at the request of the Department of Commerce, decried in its report how much the United States lagged behind Europe in aviation. In response to these findings, President Calvin Coolidge appointed a select board of prominent business leaders, headed by Dwight Morrow, to make recommendations regarding the development of aviation in the United States. The Morrow board essentially confirmed the findings of the joint commute and recommended the separation of civil and military aviation, with the former under the auspices of the Commerce Department. This pleased the secretary of commerce, Herbert Hoover, who was a strong proponent of aviation. Out of all this came the Air Commerce Act of 1926, which, in effect, got the federal government back into the aviation business, this time as a

Regulator of those budding carriers created by the Kelly Act (see the section on Federal Legislation and the Airlines).

The Post Office Department first set up short feeder routes (designed to feed traffic into the main-line trunk route) between various cities and scheduled the start of a transcontinental Columbia route once the short lines were working satisfactorily. Businessmen, lured by the Kelly Act's allowance of 80 percent of the air mail revenue to the contractor who carried it, flooded the Post Office Department with more than 5,000 bids. From these, the department chose the operators of 12 feeders, or CAM (contract air mail), routes linking cities throughout the nation (see Figure 2-1).

On November 15, 1926, the Post Office Department advertised for bids on proposals for service on two sections of the transcontinental air mail route—the New York–Chicago and the Chicago–San Francisco sections. An acceptable proposal at a satisfactory rate of compensation for the Chicago–San Francisco section was submiĴed by the Boeing Airplane Company and Edward Hubbard. This service was later incorporated as the Boeing Air Transport Company. At first, no satisfactory bid was received for the New York–Chicago section, but on March 8, National Air Transport's bid was accepted.

Service on the Chicago–San Francisco route was relinquished to Boeing by the Post Office Department on June 30, 1927. Boeing's entry into commercial aviation had far- reaching effects. To clear the Rocky Mountains, Boeing produced a new airplane, the B-40, powered by the new aircooled PraĴ & Whitney 400-horsepower (hp) Wasp radial engine and equipped to carry two

passengers in addition to its mail cargo. Subsequently, Boeing and Prattend & Whitney joined forces to become United Aircraft and Transport Company.

Service on the New York–Chicago route began on September 1, thus placing the air mail service in the same relationship with the Post Office Department as the mail service provided by the railroads, steamship lines, and other mail contractors. The air mail contracts provided the genesis for several of today's airlines. Colonial Airlines, which won CAM route 1 between New York and Boston, was the predecessor of American Airlines. Western Air Express, operator of CAM 4 from Los Angeles to Salt Lake City, eventually became part of TWA. Northwest Airlines picked up CAM 9 from Chicago to Minneapolis after the original contractor gave it up. United absorbed the operators of two western carriers, Varney Speed Lines, operator of CAM 5, and Pacific Air Transport, operator of CAM 8. After a struggle to gain majority stock interest, United also gained control of the carrier along the eastern segment of the transcontinental route, National Air Transport, which had flown specially designed planes on CAM. In the Midwest, the biggest name in automobiles, Henry Ford, emerged as a major force on the aviation scene by winning the contracts for CAM 6 and CAM 7 between Detroit, Chicago, and Cleveland. Ford's venture into aviation gave a skeptical public new confidence in air transport—if the astute auto manufacturer was willing to get into the business, there must be something to it.

Ford branched out in 1926 by acquiring the Stout Metal Aircraft Company in Stout City, Michigan, and began construction of the famous —Tin Goose . The Ford Trimotor, as it was officially designated, had three-engine reliability, as well as greater altitude capability and a larger payload capacity than any of its predecessors. From the time of its first flight in 1926 to its retirement from TWA in 1934, the Tin Goose was reliable, relatively slow at 85 knots, very strong, and rather uncomfortable.

In the meantime passenger service could only improve. In 1927, an airplane called the Lockheed Vega made its first flight, heralding the age of fast, comfortable travel for more than a mail sack and pilot.

In 1928, weather information was transmitted by teletype, and in the decade that followed, that network expanded rapidly to bring pilots the kind of information that was essential to safe, reliable service. By 1929, the Graf Zeppelin had flown around the world, and James H. Dooli_le had made the first successful instrument landing. In that same era, Hamilton Standard produced the first hydraulic variable-pitch propeller. The technology was advancing, but would any company running an airline be profitable enough to buy it?

Postmaster General Brown and the Airlines

Walter Folgers Brown was postmaster general under President Herbert Hoover in the late 1920s. An adorned from Ohio, Brown combined astute vision with a ruthless will to ensure the success of the Post Office's mission to develop commercial aviation. Both Hoover and Brown disliked reckless competition as much as they did monopolies, and they both sought industry stability, efficiency, and growth—specifically, strong companies with regulated competition. Consequently, Brown spurred the adoption of another amendment to the Kelly Act, the McNairy– Waters bill. Known as the Air Mail Act of 1930, it empowered the postmaster general to consolidate air mail routes if he thought that would serve the public interest.

Brown redrew the air map of the United States, forcing small operators out of business and awarding the bulk of the air mail business to a handful of airlines he considered to be well run, financially stable, and efficient. In May-1930, he invited the heads of the larger airlines to Washington for a series of meetings that came to be called the Spoils Conference. It was an apt name, for the spoils literally

IARE	AIR TRANSPORTATION SYSTEMS	I
	Source from Air Transportation Systems by Mike Hirst	

went to those participants who supported Brown's plan to establish three main mail routescentral, northern, and southern-out of the original CAM routes. United (a fusion of mostly west coast CAM companies) would get the northern route; Avco (the Aviation Corporation, a holding company that later became American Airlines) would get the southern route. The central route would go to a merger of Western Air Express and Transcontinental Air Transport (TAT), which had hired Charles Lindbergh to survey routes for a passenger service based on alternating rail and Ford Trimotor flights that would allow for coast-to-coast travel in the unheard-of time of 48 hours. Western had also shown considerable interest in passenger travel, although its route was for only the most rugged of individuals. Western's Harris Pop Hanshue was not the type to be forced into anything, and he fought Brown all the way, eventually compromising by accepting stock and a position in the new company. Hanshue agreed to the establishment of a new airline named Transcontinental and Western Air Express, in which TAT and Western held the majority of stock. Brown's plan seemed to succeed until 1934, when a scandal erupted in Washington. Although Brown had been quite candid about the fact that he wanted the air mail business awarded according to proven performance and financial solidity, newspaper reporter Fulton Lewis, Jr., discovered the result of Brown's philosophy. Ludington Airlines, flying the triangular Washington-Philadelphia-New York route, had bid 25 cents a mile on the mail contract between these cities but had lost out to Eastern Air Transport, a much bigger line that had bid 89 cents a mile. When his newspaper would not publish the story, Lewis approached Senator Hugo Black of Alabama, who was chairing a Senate committee investigating maritime mail contracts. When Black heard the story, he quickly added air mail contracts to his investigation.

After some lengthy hearings in which a number of supposed scandals were uncovered, Black had aroused the public and President Franklin D. Roosevelt to a point that all prior contracts were immediately cancelled. Roosevelt ordered the Army to begin flying the mail, a decision that had tragic consequences. Even though Postmaster General James Farley had argued against the cancellation, the public's wrath fell on him more than on the president when one Army plane after another crashed in poor weather that the pilots were completely unequipped to handle.

Although Black's hearings ultimately revealed no illegalities in Brown's arrangements even the supposed bidding scandal was explained to everyone's satisfaction as a more complex arrangement than it first appearedBlack still came out the winner. He talked Roosevelt into supporting a bill to separate the airframe companies from the airlines, to reopen competitive bidding, and to bar all the amended of the Spoils Conference from further participation. It was pure punitive politics, but at least the Army was out of the mail business. Not only had a number of pilots lost their lives, but it had cost the Army \$2.21 a mile to fly 16,000 miles of routes, compared to 54 cents a mile to cover 27,000 miles for the airlines.

The Air Mail Act of 1934 was signed into law by President Roosevelt after Senator Pat McCarran's effort to legislate an independent regulatory body was defeated. The act authorized new one-year contracts that were subject to review before renewal. The Interstate Commerce Commission was involved as a regulator of rates, and the secretary of commerce was empowered to specify what equipment was suitable for each route. To placate smaller airlines anxious to acquire portions of the big routes, Postmaster General Farley added a provision that barred all prior contract holders from bidding anew. Obviously, this meant the end of the airlines as an industry. The government that had created them under Brown was now preparing to destroy them under Farley. Farley privately advised all the airlines to reorganize, which is how American Airlines, Eastern Airlines, and United Airlines all came to be. Of greatest consequence was the provision that severed aircraft manufacturers from the airlines themselves. Boeing had to pull out of United; Avco gave up American; North American sold its TWA holdings; and General Motors surrendered its stock in both

Eastern and Western. A new era had dawned, one in which the airlines would guide their own destinies.

The Turning Point for the Airlines

Certain aspects of the industry were looking up. Both the Boeing 247 and the DC-1 had made their first flights during 1933, rendering immediately obsolete such antiquated fixtures as the Trimotor and the Curtiss Condor, the last of the biplane transports. Boeing's all-metal, low-wing, twin-engine monoplane was the first modern airliner. Nevertheless, the 247 was not a success, serving as an illuminating example that in the airliner market, the design that is first to the finish line does not necessarily win the race. The 247 was spectacular: faster than most fighter planes and able to carry 10 passengers in unaccustomed luxury. It won the Collier Trophy for speed and endurance in 1933, as well as the favors of William A. Pa_erson, who became president of United Airlines after the previous president resigned during the Brown scandal. Pa_erson bought 60 of the Boeings for \$4 million, at the time the largest single purchase of airplanes in history—and a bigger order than Boeing could really handle. order tied up the company's assembly lines for a year, forcing TWA and American to look elsewhere for planes. Unfortunately for Boeing, their search took them to a small manufacturer headed up by Donald Douglas.

The 247 originally was to have been built with the new Pra_ & Whitney air-cooled Hornet engines, but United's pilots vetoed those engines; they trusted only the reliable Pra_ & Whitney Wasp engine. The 247 would have carried 14 passengers with Hornets, but the United version could carry only 10 with the smaller Wasps, and thereby Boeing won the battle but lost the war.

In 1932, Jack Frye, president of TWA, had gone to Douglas with a proposal for a trimotor airliner. Douglas knew that the Wright Cyclone would eliminate the need for the third engine, offering seats for 14 in a twin-engine airplane. Thus, when Boeing slammed the door on TWA and American, Douglas was able to show them something be_er—four more passengers than the 247 could carry for the same operating cost. The resulting DC- 1, whichquickly stretched to the DC-2, was a colossal gamble for Donald Douglas, and the debt he incurred developing it was not paid off even by TWA's eventual order for 25 planes. Boeingsold 75 of the 247s—but that was all. Lufthansa bought two that served as models for some of Germany's World War II bombers, so advanced was the 247's design and performance.

United soon switched to the Douglas airplanes as well, in order to remain competitive with American and TWA. But if the 247 had been built with the proper engine, there might never have been a Douglas airplane to consider. The 247 caused a setback for Boeing, but it did serve as the stimulus for the DC family, a line of airplanes that are generally credited with moving the airlines from their pre-1933 red-ink days to times of solid profit. The DC-3, which was introduced as the Sleeper Transport (the DST) in response to a specification written by American Airlines' C. R. Smith, not only increased the speed and comfort of travel, thereby winning passengers who had not been willing to brave an airliner before, but also operated reliably and profitably. The plane was incredibly strong, an attribute that is largely credited to an engineer named Jack Northrop. Its development also introduced the importance of operating costs to airline managers, who were mostly new to the business and therefore willing to try new ideas. The DC- 3 was the first airplane to in still a feeling of confidence in air travel, as measured by the fact that its safety record encouraged the introduction of the first air travel insurance in 1937.

The Arrival of the Professional Airline Manager

Once the 1934 Air Mail Act had become law, a new group of managers emerged who would prove to be the most dominant personalities thus far in the short history of air travel. The pioneers had been long on courage, but they came up short when it came to business acumen. Curiously, few of the

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leaders we now associate with their respective companies actually founded their airlines. The major exception is Juan Tripe, the former Navy pilot who

Launched Pan American World Airways in 1927 with a rented seaplane because the Fokker he ordered didn't show up on time. Another exception was Tom Braniff, whose brother Paul was

One of his first pilots. A third founder, though he came along later, was the colorful Bob Peach of Mohawk Airlines (now part of US Airways). For the most part, however, the men who became the giants of the industry worked their way up from less exalted positions. For example, William A. Paterson, who boldly signed for \$4 million worth of Boeings, was only a vice-president at United when the massacre of 1934 moved him up. As late as 1934, afterthe Air Mail Act had gone into effect, C. E. Wolman was only general manager of Delta, but he would lead the company's development as its president in the decades to follow. The president of Eastern was Ernest P. Breech; Eddie Rickenbacker didn't join until the following order tied up the company's assembly lines for a year, forcing TWA and American to look elsewhere for planes. Unfortunately for Boeing, their search took them to a small manufacturer headed up by Donald Douglas.

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Still, aviation in all its forms contributed to the war effort. Everything that flew became at least quasimilitary: the Civil Air Patrol went out on coastal patrols, and the airlines contracted the bulk of their fleets to the Army. The military also enlisted most of the pilots who had staffed the airlines and routes were revised drastically to allocate the remaining resources to the war effort rather than the needs of the travelling public. Production was converted overnight: the DC- 3 became the C-47 and was even more legendary in its accomplishments as a military airplane than in its civilian counterpart. At the beginning of the war, U.S. transports were the most highly evolved aircraft the military had, and certainly the most tried and tested. The war shrank the airlines themselves to insignificance, but the industry had never been more than the sum of the skill and equipment that turned it into an efficient military force as easily as they had made it a profitable business.

The Post war Years

Out of World War II came the DC -4 and the Constellation, two high -performances, long range airplanes that later prepared the industry for the jet era. The C-54 (the military designation for the DC-4) had its beginnings back in 1936 as the DC-4E, an abortive design that combined the forward end of a DC-3 with four engines and a triple tail. Meanwhile, George Mead of Pratt& Whitney had undertaken the task of getting that company back into the transport business; its military success had been phenomenal, but Wright Aeronautical had dominated the commercial market with the DC-3. The new Par_ & Whitney R-2000 engine met the specifications for the final version of the DC-4, an entirely new Douglas design that first flew in 1942, just in time to become the Army's C-54 Sky master. Simultaneously, Lockheed was building the Constellation, which had Wright engines, a pressurized airframe, and the triple tails that Douglas abandoned; it first flew in 1943. It is significant that air cargo became a worthwhile notion during the war. Freight was first carried in the C-47, the C-54, and the Constellationthe old passenger carriers and later in airplanes such as the C-82s, which were designed specifically to move freight. Although the airlines could not benefit financially from these new airplanes until after the war, it mattered little. The aircraft existed, and the fact that the military produced them in large numbers simply made them available cheaply as post-war surplus.

The complex operations of war also hastened the improvement of communications techniques, and radar became a high-priority project that would lay the foundation for modern air traffic control. Military air traffic operations in high-density environments became a valid model to be further improved upon and modified to fit the needs of the airlines.

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The immediate post war era was a stagnant time for the airlines. President Harry S. Truman's administration was plagued by heated rivalries and political infighting over routes and revenues. With thousands of aviator's available after the war, a large number of airlines sprang up. Trunk routes were already taken by the prewar companies, but many feeder routes were up for grabs. The established carriers viewed with horror the thought of government subsidies for new feeder lines, arguing that they shout Aeronautics Board assured the larger carriers that the newly established feeders would be carefully monitored and not allowed to compete with airlines flying the trunk lines. Some of the first feeders established were Allegheny, Mohawk, Piedmont, North Central, Frontier, Bonanza, Ozark, and Pacific.

Overexpansion furnished enough trouble for the airlines, but the non-scheduled airlines that sprang up all over the nation provided more. These airlines, naturally, made runs between major population centers, which cut into the trunk lines'traffic. The Berlin airline in 1948–49 represented an unequalled opportunity to develop experience in high-volume air freight and contributed to the sense of optimism about air freight as a viable business. Independent lines specializing in carrying only freight were formed, and the first experiments in using helicopters to carry the mail to inner-city heliports were conducted. In 1947, Los Angeles Airways succeeded in gaining approval for the first scheduled helicopter service.

Boeing tried to bounce back with its 377 Strat cruiser, modeled acer the military B- 29 Superfortress. Its success was limited, however, and Boeing turned its attention to military jet aircraft. Meanwhile, Conair and Martin twin-engine planes with pressurized cabins flew short-haul routes to feed the evergrowing giant airlines that crossed the entire country in nonstop leaps. Aviation records fell as new and improved models of Constellations, DC -6s, and DC-7s with reciprocating power plants appeared. The United States had emerged in the postwar years as the aircraft manufacturing leader.

The British aircraft manufacturing industry met with government officials after the war to decide whether to try to challenge the lead of the United States with conventional transports or to take another approach. They decided to leapfrogto gamble on producing the first jet airliner. The result was the DE Havilland Comet jetliner. It made its first flight in July 1949, and it entered service with BOAC in May 1952. In January 1954, a Comet plummeted into the Mediterranean, killing all 35 passengers and crew members; in April 1954, a second Comet ripped apart and plunged into the sea after takeoff from Rome. All Comets were grounded while officials conducted a thorough investigation to ascertain the cause of the crashes. In February 1955, the investigators determined that metal fatigue in the hull had led to explosive decompression.

Technological advances were coming so fast that the old pioneers of the airlines were soon le_ behind. Airplanes quickly became machines of awesome complexity, requiring systems no one person could ever entirely understand. Increasingly, it was the government that recognized this, and beginning in 1947, the Civil Aeronautics Authority (CAA) began certifying three new classes of flight personnel: flight radio operators, navigators, and engineers, a symbol of the era of the technocrat. Landings became routine at 42 terminal airports used by 12 of the airlines. In 1948, three engineers at the Bell Telephone Laboratories invented the transistor, while distance-measuring equipment (DME) and very high frequency (VHF) omnirange loomed as the answer to a need for improved air navigation aids. By 1951, Par_& Whitney was testing its 10,000-poundthrust J57, which would make the development of the Boeing 707 possible. Very quietly, in 1953, a study was completed showing for the first time that the airplane had become the prime mover of travelers on trips of more than 200 miles. This only confirmed what the young executives in the airline marketing departments already knew. The way to win the public was to sell not transportation, but travel, and that took new and ingenious methods.

If U.S. engineers weren't willing to experiment with turbojets, they could at least go halfway with turboprops, and Capital Airlines tried the British-built Vickers Viscount amid pressed provide the feeder service. The Civilparties that featured demonstrations of how one could balance a quarter on the edge on one's meal tray, so smooth were the new turbine engines. But when Lockheed tried the same approach with its Electra turboprop, the result was one of the most expensive recall campaigns ever. Although the airplane eventually proved to be one of the most efficient ever built, its image suffered when critics questioned its structural integrity. Lockheed eventually redesigned the wings and engine nacelles on 165 of the airplanes.

Boeing had never really prospered in the commercial business since the DCs had stolen the thunder from its 247. The 307 and 377, though praiseworthy for their implementation of revolutionary features, had not really been successful. Fortunately, Boeing had been blessed with an endless succession of contracts for heavy military equipment that kept it afloat.

At great financial risk, Boeing built a jet tanker, the military KC-135, whose purpose was to fuel the Boeing-built B-47 jet bomber. The air force tested the plane and bought it. Boeing then approached the airlines, proposing a jet airliner based on the Boeing jet tanker. The airlines were lukewarm to the proposal and declined to invest any money in research. Once more, Boeing risked its own funds, this time to develop the Boeing 707.

When, in 1955, Pan Am announced its order not only for the 707 but also for the Douglas DC- 8, Boeing had spent \$185 million on jet transport development. It marked the end of one era, and the beginning of another.

MATURITY—JETS ARRIVE: 1958–1978

The jets were coming, and by 1956 the CAA recognized the inevitable and held a conference to plan for the jet age. The challenges were enormous, not only for the airlines, for whom 30 years of parts and maintenance experience became obsolete overnight, but also for the government, because safe operations were their responsibility. Then, in 1956, an event occurred that defied all the odds: a TWA Super Constellation and a United DC -7 collided over the Grand Canyon, killing 128 people. Suddenly, it was a crowded sky, and the outcry for reform was loud and clear. The answers, of course, were sought in technology. If a pair of conceptually obsolete piston airliners could have a midair collision, what would happen with jets, which went 50 percent faster? The seemingly impossible collision between two airplanes in what had once seemed a boundless sky was a pivotal event in the history of airline travel, for it brought the issue of the control of each flight by some central authority to the fore, made air traffic control mandatory, and increased demands for precision. It also paved the way for the next major piece of legislation The Grand Canyon midair collision was followed by two more bad accidents, and in 1958, there was a virtual stampede to push through Congress a law creating a new Federal Aviation Agency (FAA), an independent and comprehensive government agency to control all aviation matters, both civil and military. Centralized air traffic control began less than a month after the bills were introduced. President Dwight D. Eisenhower pressed for passage, and the FAA was born.

Just as the turboprops entered service in 1958, the 707 began flying overseas routes. The turboprop aircraft had a relatively short life with the major carriers. It was American Airlines that began 707 services between the coasts a year later. With the advent of the 727, one of the most efficient transport airplanes ever built and one that became as widely flown as the DC-3, and the DC-9, the airlines soon disposed of all their reciprocating propeller equipment. For a while, Eastern used some older airplanes on its shuttle flights between the northeast corridor cities of Boston, New York, and Washington, but they were soon replaced.

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On December 30, 1969, Boeing achieved certification of an airplane that revolutionized airline travel forever. Just as the original B-707 brought vibration-free, over-weather, jet engine flying to passengers, the giant 747 was to bring low-cost travel to the masses. Once again, Pan Am led the way by introducing jumbo-jet service across the Atlantic in January 1970. An economic downturn dried up orders for the plane between 1969 and 1972, but after that initial setback, orders began to flow in a steady stream.

The Boeing 747 was unmatched. It was able to carry about 380 passengers in an 8- or even10-abreast, twin-aisle, mixed-class layout and brought a new term to commercial aviation: —wide-body. The humpback profile of the airplane resulted from an early decision to maximize freight-carrying capability; the tilt-up nose on the 747F (freighter) and 747C (convertible) versions allowed direct insertion of cargo containers. Doing so required a cockpit that was removed from the main deck and a generous after body for streamlining, and, at Juan Trippe's insistence, an upper-deck, first-class lounge was added in the area behind the cockpit.

The Boeing 747 has reigned supreme over the world's air routes for more than a quarter of a century. More than a thousand 747s have already been built, and production continues. Wisely, other manufacturers did not try to challenge Boeing head-on. The tri-jet Douglas DC-10 and the Lockheed L-1011, under development at the same time as the 747, were only about three-quarters of its size. Containing about 270 seats, the planes were intended to satisfy the requirements of air routes that did not generate sufficient traffic to justify the deployment of the giant Boeings. The DC-10 entered service on August 5, 1971, and theTriStar on April 26, 1972. Both suffered severe setbacks. A DC-10 suffered a spectacular crash at the world's busiest airport, Chicago's O'Hare, on May 25, 1979. Production of the

TriStar was disrupted by the bankruptcy of its engine manufacturer, Rolls-Royce. A latecomer to the wide-bodied airliner field was the Airbus. It was first conceived simultaneously by Hawker -Siddeley, which had taken over DE Havilland, in Great Britain and by Briquet-Sud in France. The basic design of this twin-engine variant on the wide bodied principle took shape in the late 1960s. The wings for what became the A300 series were built by a European consortium of airframe manufacturers. Air France put the first version of the Airbus, as it quickly became known, into service in May 1974.

Boeing had not been neglecting other projects during the years of the 747 program. The three-engine 727 short-haul airliner began as a 100 -seat regional carrier, eventually stretching into lengthened versions that matched the 707's length. Both the 727 and the 737 used the fuselage cross section of the 707 series, giving short-range customers amenities similar to those found on the longer trips. The twin-engine 737, certificated in July 1967, was designed to compete with Douglas's DC-9 .Since the jets took over, the airline industry has introduced one technological advancement after another: flight recorders, weather radar, terrain-avoidance systems, and so on. During this era, the airlines passed from a period of high risk to a period of virtually no risk at all. With the passage of the Airline Deregulation Act of 1978 (see the section Federal Legislation and the Airlines), the airline industry moved into an era of new challenges.

ECONOMIC DEVELOPMENTS PRIOR TO DEREGULATION

The period from 1938 to 1978 witnessed truly phenomenal growth in both domestic and international air transportation. Over the years, U.S. airlines received many new route1authorizations, domestic and international. Table 2-1 shows the growth in the number of certificated domestic route miles of the leading carriers during 40 years of regulation. The number of U.S. city pairs connected by scheduled airline service grew in step with expanded route miles. Internationally, limited service was provided in 1938 by a handful of scheduled U.S. airlines (principally Pan American Airways and its related

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companies) and a half dozen or so significant foreign airlines. By 1978, these numbers had increased to 21 U.S. and 73 foreign airlines.

Air passenger traffic also grew at an astonishing rate. The number of passengers (domestic and international) carried by U.S. airlines increased from a little over 1 million in 1938 to almost 267 million in 1978. In addition, in 1978, foreign airlines carried some 16 million passengers to or from the United States. With increases in average length of journey, there was an even greater growth in U.S. airline passenger miles, from 533 million in 1938 to 219 billion in 1978. The air transport industry thus emerged as one of the nation's major industries. Over the four-decade period, revenues increased from \$58 million to \$22.8 billion, and total airline assets increased from under \$100 million to over \$17 billion.

The air transport industry also became a major employer. Total direct airline employment increased from about 13,000 to well over 300,000. In addition, hundreds of thousands of people were employed in the manufacture of civil transport aircraft, engines, and accessories; at airports; in travel agencies; and in the vast range of other related service, supply, and support activities.

Technological development was spectacular, not just in aircraft but in the air transport system infrastructure as well. In terms of aircraft, this 40-year period witnessed the evolution from the propeller -driven, 21-passenger DC-3 to the 400- seat, wide-body Boeing 747 jet that, in addition to a full passenger load, has cargo capacity equal to the load carrying capability of five DC-3s. Aircraft nonstop range, with full payload, grew to over 6,000 miles.

Accompanying these developments were quantum improvements in safety, speed, comfort, and overall convenience for the users of air service. A truly integrated air transport system was developed that enabled the public to buy tickets from virtually any airline (and from many thousands of travel agents) for travel on multiple airlines and to check baggage at the point of origin for delivery at the destination regardless of how many airplane or airline changes were made in route.

At the same time, technological advances combined with economies of scale to produce lower unit costs, helping make it possible to hold the line on prices over this 40-year period. Despite a consumer price inflation rate of almost 400 percent from 1938 to 1978, average fares per passenger mile remained remarkably stable (see Table 2-2). The increase from 1968 to 1978 reflected not only acute inflation but also the sharp fuel cost increases following the 1973 oil embargo.

The air transport industry also met the congressional objective of assisting the national defence. As reported by the CAB in its 1942 Annual Report to Congress: —Pearl Harbor brought real meaning and new force to the national defiance standard so wisely written into the Civil Aeronautics Act during peacetime. The airlines, domestic and international, went on wartime footing and contributed significantly to the war effort. Subsequently, they helped break the Berlin blockade, provided important contributions in the Korean and Vietnam wars, and furnished emergency and evacuation assistance in dozens of other critical situations around the globe. And by 1978, the formal Civil Reserve Air Fleet, available with crews for

military call-up at defined stages of national emergency, contained 298 commercial aircraft, of which 216 were large intercontinental units. The U.S. air transport system, by far the largest in the world, was also the best in just about every respect. And this contributed, in no small measure, to the worldwide supremacy of the U.S. aerospace industry, exporting as it did many billions of dollars' worth of aircraft, engines, components, and parts.

All of this was accomplished through private enterprise with an early phase out of government subsidies except for limited types of service in the public interest. Exact early figures do not exist, because the CAB did not identify the —compensatory element in total mail pay until 1951. For fiscal 1951, slightly over \$75 million was paid in subsidies, equal to slightly over 7 percent of total industry revenues. In 1951, subsidy recipients, by category, were:For calendar year 1977, by coincidence, almost the same levels of subsidies (\$76.7 million) were distributed, but none went for domestic trunks or international services, which had long functioned without government financial support. The recipient groups in 1977 were:

Local service	\$72.2 million
Alaskan carriers	\$ 4.5 million
Total	\$76.7 million

Subsidies in 1977 represented only 0.3 percent of total industry revenues. The 40 -year period of air transport regulation saw a steady increase in the number of operators on specific domestic routes. In 1978, few markets with significant traffic existed that were served by only one airline. And in international service, there was a steady and substantial increase in the number of operators (U.S. and foreign) over virtually all commercially important routes.

This 40-year period also saw changes in the structure of the U.S. airline industry. A number of the original —grandfather trunk-line carriers (5 of the original 16) merged with or wereacquired by other airlines; there were no bankruptcies among them. During the same period, new categories of carriers, as well as new carriers, were licensed, including 8 local-service and 3 all-cargo companies, and 10 charter airlines. This larger group played a significant role in offering lower-priced transportation and developed a strong presence in certain markets, particularly for transatlantic flights. Despite problems and inadequacies, few could reasonably deny the brilliant success of the 1938 regulatory scheme. There was a high level of public satisfaction with U.S. airlines. A U.S. News & World Report survey revealed that out of 21 defined categories of U.S. industry, the airlines were rated the highest for -giving the customer good value for money. In only one respect did the airlines perform poorly: compared with other broad industry groups, the airline business was not highly profitable? Coincidentally, 1978, the last year of regulation, was by far the most profitable year over the 40-year period. Any review of airline profitability must also take into account the extremely cyclical nature of the business. It is highly leveraged, because the marginal cost of additional traffic (and the marginal savings from less traffic) at any given level of capacity is very low. As a result, the swings in profitability from recession to good times and back to recession can be very wide. This is well illustrated by how the 1970-71 and 1974-75 recessions affected airline financial performance (see Table 2-3). It is interesting to note that ATA computations of rate of return on investment showed, for example, positive returns of 1.2 percent in 1970, when the industry reported a net loss of \$201 million, and 2.5 percent in 1975, when it reported a net loss of \$84 million. Profit margin provides a meaningful financial yardstick. Based on these computations, airline profit margins from 1967 to 1977 averaged only 1.7 percent, versus 4.8 percent for U.S. manufacturing companies.

FEDERAL LEGISLATION AND THE AIRLINES

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The authority of the federal government to regulate interstate and overseas aviation and air transportation derives from the Constitution of the United States, which grants to Congress the right to regulate interstate and foreign commerce, to regulate the postal service, to make treaties with foreign nations, and to provide for the national defense. The rationale for regulation is rooted in the economic and physical characteristics of the air transport industry. The major reasons are listed here:

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Source from Air Transportation Systems by Mike Hirst

To stabilize the industry. The air transportation industry is a public utility that is important to the commercial and social welfare of the nation. The need to stabilize modes of transportation so that they could serve the public at reasonable prices spurred the introduction of economic regulation of water transportation, railroads, and, later, highways. In the case of air transportation, the industry was somewhat unstable in its early years of growth, even though safety regulations and federal subsidies through air mail contracts were in place from the beginning. Industry instability was one of the primary reasons for bringing air transportation under a system of regulation.

Air transportation's early years were characterized by fierce competition amongnumerous budding carriers, fluctuating prices, unreliable service, and high turnover among carriers. Overcapacity in the industry and the competitive bidding process for air mail contracts were said to have led to absurdly low bids and disastrous price wars. This atmosphere was not conducive to investment by the financial community, and without outside capital funding, the fierce little competitors that made up the industry in its early years could not acquire the equipment they needed. Later, in the early 1930s, the air carriers themselves sought federal regulation, realizing that the history of transportation demonstrated that the absence of such regulation led to evils from which not only the public but also the industry itself would suffer. By 1938, the air transportation industry was experiencing critical financial difficulties: many of the major lines faced the threat of bankruptcy, and much of the original investment in airlines had been dissipated. Financial difficulties were also aggravated by a series of accidents in the winter of 1936–37 that undermined public confidence. The fact that rail and highway transportation was already regulated set a precedent for regulation that encouraged its enactment in air transportation.

To improve air safety. The industry was, and still is, largely dependent on government aidto maintain the safe flow of traffic. Federal regulation of air transportation safety was in effect from the early years. It was recognized that safety regulation could not reach its maximum effectiveness if the industry was unstable and if the carriers were financially weak and unable to afford the necessary safety precautions and devices. Therefore, economic regulation was intended, in part, to stabilize air transportation so that the carriers would have the financial capacity to pay for whatever was needed to conform with safety regulations pertaining to the design, operation, and maintenance of aircraft.

To reduce cash subsidies. Another reason, although minor, for regulating air transportationwas the fact that air carriers had been subsidized through the air mail program since the mid-1920s. It was believed that the subsidies needed could be reduced by stabilizing the industry through economic regulation. A financially strong and stable airline industry would need smaller subsidies from the federal government.

Other reasons for regulation included the fact that the industry used the airspace over the entire United States, over other nations, and over international waters. Consequently, it naturally fell under federal rather than state jurisdiction. Another reason was the industry'srole in the national defence. This was evidenced as early as World War II, when the airlines, flying under contract for the military, provided the backbone of the Air Transport Command. Under contracts with the military for airline services, the airlines played a significant role during the Korean and the Vietnam wars. In addition, a joint program between the Department of Defence and the airlines, the Civil Reserve Air Fleet (CRAF), was designed to augment military airline capability in the event of a national emergency.

Early Federal Legislation

The first steps the federal government took to regulate aviation and air transportation occurred in connection with the development of the air mail service. In May 1918, the air mail service was

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inaugurated on an experimental basis by the Post Office Department and the Army. In August of the same year, the service was taken over as a Post Office Department operation. On February 2, 1925, Congress enacted the Contract Air Mail Act, usually known as the Kelly Act, and as such gave birth to the airline industry. This law authorized the postmaster general to contract with private individuals or companies engaged in air transportation service for the transportation of air mail. By 1927, all the air mail services of the Post Office Department had been turned over to the air transportation companies, and new routes were established to be operated by air mail contract carriers. The effect on air passenger transportation of the establishment of contractual relationships between the Post Office Department and the air mail carriers can scarcely be overemphasized. The subsidies received by the air mail contractors enabled a number of airlines to establish passenger services. Indeed, it would have been impossible for some companies to exist without the air mail contracts. The Kelly Act was amended in 1926 to provide higher rates of compensation. Subsequent air mail legislation was important because of the relationship of this type of regulation to the broader legislation dealing with the regulation of air transportation. The pioneer legislation of this type, because it laid the foundation for all future regulation of air transportation, was the Air Commerce Act of 1926, also known as the Bingham-Parker Act.

The Air Commerce Act of 1926

The Air Commerce Act of 1926 imposed on the secretary of commerce and the Department of Commerce the duty of promoting and fostering the development of commercial aviation in the United States. The act authorized the Department of Commerce to encourage and develop facilities necessary for air navigation and to regulate and maintain them. The act did not initially create a new bureau within the Department of Commerce. Rather, the intention was to distribute the duties imposed by the act among the then existing agencies of the department.

The objective of the Air Commerce Act was to stabilize civil or commercial aviation in such a way as to attract adequate capital to the fledgling industry and to provide it with the assistance and legal basis necessary for its development. The law emphasized the federal government's role in the development of civil air transportation more than it stressed its responsibility for regulating the business aspects of air transportation. The act was designed to encourage the rapid development of commercial aviation, as indicated by the legislative history of the act.

In introducing the bill that became the Air Commerce Act, the Senate Committee on Interstate Commerce stated that —although Americans built the first airplanes capable of flight, and were the first to learn how to fly heavier-than-air machines, and hold more world records than do the citizens of any other nation, commercial aviation has not advanced as rapidly in the United States as had been hoped and expected. This act defined air commerce as transportation, in whole or in part, by aircraft, of persons or property for hire, and the navigation of aircraft in furtherance of or for the conduct of a business. The act made it the duty of the secretary of commerce to encourage air commerce. The regulation of aviation provided for in the act included the licensing, inspection, and operation of aircraft; the marking of licensed and unlicensed aircraft; the licensing of pilots and of mechanic engaged in aircraft work; and the regulation of the use of airways. Several different governmental agencies or departments were empowered to perform functions relative to carrying out the provisions of the act:

1. The Department of Commerce was entrusted with the administration and enforcement of major portions of the act. An assistant secretary for aeronautics was appointed in 1927 to administer the duties assigned to the department.

- 2. The secretary of the treasury was given the duty of providing regulatory rules for entry, clearance, and customs regulations for aircraft engaged in foreign commerce.
- 3. The secretary of labor was empowered to deal with all immigration problems relative to air transportation.
- 4. The Weather Bureau of the Department of Agriculture was authorized to supply meteorological information.
- 5. The secretary of war was authorized to designate military airways.
- 6. The Bureau of Standards of the Department of Commerce was directed to undertake R & D to improve air navigation facilities.

Through this distribution of functions in connection with aviation and air transportation, Congress sought to utilize as many of the existing governmental agencies as possible, thus avoiding or reducing the need to create additional and duplicating federal agencies especially for air transportation and aviation. Consequently, no separate bureau was initially set up in the Department of Commerce. However, in July 1927, a director of aeronautics was appointed, who, under the general direction of the assistant secretary for aeronautics, was in charge of the work of the Department of Commerce in the administration of the Air Commerce Act.

In November 1929, because of the increasing volume of work incident to the rapid development of aviation, it was necessary to decentralize the organization. Three assistants

and the staffs of the divisions under their respective jurisdictions were assigned to the assistant secretary of commerce for aeronautics. These included a director of air regulation, a chief engineer of airways, and a director of aeronautics development to assist in aeronautical regulation and promotion. The organization was known as the Aeronautics Branch of the Department of Commerce.

The work was further reassigned by executive order of the president in 1933, so as to place the promotion and regulation of aeronautics in a separately constituted bureau of the Department of Commerce. An administrative order of the secretary of commerce provided for the establishment of the Bureau of Air Commerce in 1934. The bureau consisted of two divisions, the Division of Air Navigation and the Division of Air Regulation.

A revised plan of organization for the Bureau of Air Commerce, adopted in April 1937, placed all the activities of the bureau under a director, aided by an assistant director, with supervision over seven principal divisions: airway engineering, airway operation, safety and planning, administration and statistics, certification, inspection, and regulation. A policy board was formed to deal with all manners affecting policy within the bureau, and an advisory board, consisting of civilian and other representatives of all aviation interests, was appointed to advise the bureau.

Additional Air Mail Acts

The Air Mail Act of 1930, known as the McNary–Waters Act, was passed by Congress on April-29, 1930. It provided the postmaster general with unlimited control over the air mail route system. The postmaster general could now extend or consolidate routes if he thought it would serve the public interest. The act also tightened the provisions under which contractors were reimbursed for carrying the mail and provided additional remuneration for contractors flying multi-engine aircraft and using the latest navigational aids .In February-1934, the postmaster general annulled all domestic air mail contracts, and the transportation of the mail was assigned temporarily to the Air Corps of the U.S. Army. This action was taken because the postmaster general had evidence that there was a conspiracy to defeat competitive bidding.

The arrangement with the Air Corps continued from February 20 to May 16, 1934. Then, after the reorganization of the commercial air transportation companies according to government requirements as a precondition to submitting bids for air mail contracts, the commercial companies submitted bids, and new contracts were awarded.

The Air Mail Act of 1934, passed on June 12 and known as the Black–McKellar Act, provided temporary contracts and gave the Interstate Commerce Commission (ICC) the responsibility of periodically adjusting the rates of compensation to be paid the air transport companies for the carriage of the mail within the limitations imposed by the act. The ICC was required by law to review annually the rates of air mail pay to ensure that no company was earning unreasonable profits. Each air mail contractor was required to submit for examination and audit by the ICC its books, accounts, contracts, and business records and to file semiannual reports of all free transportation provided. The ICC also was authorized to invest agate any alleged unfair practices and competitive services of companies transporting air mail that adversely affected the general transport business or earnings on other air mail routes, and to order the practices or competition to be discontinued if unfair conditions were found to exist. The act also provided that after July 1, 1938, the aggregate cost of air mail transportation to

the government could not exceed the anticipated revenue from air mail. The ICC organized the Bureau of Air Mail to administer the regulation of air mail compensation under its direction.

In addition, the act separated the manufacturing companies from connections with airlines and forbade interlocking directorates, overlapping interests, and mutual stock holdings. By 1938, two general categories of —air carriers had developed. The first, economically more significant, group was composed of the air mail contractors that flew over established routes and transported persons, property, and mail. The second group, the so-called fixed-base operators, was composed of persons operating airports, flying schools, crop-dusting services, and so forth, who also carried persons and property on an air taxi basis in small, and non transport-type aircraft.

The Civil Aeronautics Act of 1938

On June-23, 1938, the Civil Aeronautics Act was approved by President Roosevelt. This act substituted a single federal statute for the several general and air mail statutes that up to this time had provided for the regulation of the aviation and air transportation industry. The act placed all the functions of aid to and regulation of aviation and air transportation within one administrative agency consisting of three partly autonomous bodies—a five-member Civil Aeronautics Authority (CAA), a three-member Air Safety Board, and an administratorand exempted to demarcate executive, legislative, and judicial functions.

Members of this composite agency or administration were appointed by the president with the advice and consent of the Senate. No term was stated for the administrator, but members of the other two agencies were appointed to office for terms of six years. The act required members of the three agencies to devote full time to their duties and forbade them from having any financial interest in any civil aeronautics enterprise. The five members of the Civil Aeronautics Authority performed quasijudicial and legislative functions related to economic and safety regulations. The administrator performed purely executive functions related to the development, operation, and administration of air navigation facilities, as well as promotional work in aviation. The Air Safety Board was a quasiindependent body created for the purpose of investigating and analyzing accidents and making recommendations to eliminate the causes of accidents.

The personnel, property, and unexpended balances of appropriations of the Bureau of Air Commerce of the Department of Commerce and of the Bureau of Air Mail of the Interstate Commerce

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Commission, which had administered air mail payments under the Air Mail Act of 1934, were transferred to the new Civil Aeronautics Authority. The transfer of the responsibilities of the Bureau of Air Commerce to the Civil Aeronautics Authority, affected in August 1938 under provisions of the Civil Aeronautics Act, brought to a close a 12- year period during which the development and regulation of civil aeronautics were under the jurisdiction of the Department of Commerce.

The Civil Aeronautics Authority exercised all quasi-legislative and quasi- judicial powers conferred by the act and all executive powers of appointment with respect to its officers and employees. It took control of the expenditures of the administrator and the Air Safety Board and of all other executive powers of appointment with respect to the exercise of these quasi-legislative and quasi-judicial powers.

The administrator, appointed by the president, exercised executive powers with respect to the development of civil aeronautics and air commerce; the fostering, establishment, and maintenance of air navigation facilities; and the regulation and protection of air traffic.

The Air Safety Board was appointed by the president, by and with the approval of the Senate. It acted independently of the Civil Aeronautics Authority, and in performing its investigations of accidents, it reported on the facts and probable causes and recommended preventive measures to avoid future accidents.

The Civil Aeronautics Authority was directed by Congress, in the declaration of policy of the Civil Aeronautics Act, to regulate air transportation in the public interest by performing six functions:

- 1. Encouraging and developing an air transportation system adapted to the present and future needs of domestic and foreign commerce, the postal system, and national defense
- 2. Regulating air transportation so as to preserve its inherent advantages, promoting the highest degree of safety and sound conditions in the industry, improving relations among air transport companies, and coordinating transportation by air carriers
- 3. Promoting adequate, economical, and efficient transportation service by air carriers at reasonable charges, and prohibiting unjust discrimination, undue preferences or advantages, and unfair or destructive competitive practices
- 4. Preserving competition in keeping with the sound development of an air transportation system for commerce, the mail service, and national defence
- 5. Promoting the development of air commerce and safety
- 6. Encouraging the development of civil aeronautics

The act extended federal regulation to all phases of aeronautics, to all persons engaged in flying, and to all instrumentalities of aviation with the exception of the actual acquisition and operation of airports. This was accomplished by what has been termed a rather unusual use of definitions. *Air commerce* was defined by the act to mean all interstate, overseas, or foreign air commerce, or the transportation of mail by aircraft, or any operation or navigation of aircraft within the limits of any civil airway, or any operation or navigation of aircraft that directly affected or that might endanger safety in interstate aviation, because a private pilot might use an airway in intrastate operation that might endanger the safe conduct of interstate commerce.

Under several reorganization plans in 1940, the Air Safety Board was abolished and its functions transferred to the five-member Civil Aeronautics Authority, which was redesignated the Civil Aeronautics Board (CAB). The administrator of civil aeronautics (whose organization was then

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known as the Civil Aeronautics Administration, or CAA, and later as the Federal Aviation Agency, or FAA) was placed under the Department of Commerce. The respective duties of the board and the administrator were delineated in broad outline. The CAB, although administered within the Department of Commerce for housekeeping purposes, retained its status as one of the so-called independent regulatoryagencies, such as the Interstate Commerce Commission, the Federal Communications Commission, the Federal Power Commission, and the Securities and Exchange Commission.

Under the later 1958 Federal Aviation Act, the board was designated an —independent agency. The FAA, successor to the CAA, was not assigned to any executive department, but was considered an —executive agency as opposed to an independent regulatory commission. *Economic Functions of the CAB*

The broad language of the Declaration of Policy, with its somewhat conflicting objectives, le_ the CAB with considerable discretion in its administration of the act. The CAB's decisions were final, subject to court review, but even here the act provided that the findings of fact by the CAB, if supported by substantial evidence, shall be conclusive. This was a significant obstacle to efforts to overturn CAB decisions, particularly because the findings in most route and rate proceedings (which were at the heart of the regulatory scheme) were predictive or judgmental in character.

Whatever the complexities encountered in practice, the licensing system was simple inconcept: no one could engage in the business of public air transportation unless authorized to do so by a certificate of public convenience and necessity issued by the CAB. To obtain such certificates, applicants were required to convince the CAB that they were fit, willing, and ableto perform the proposed transportation properly and that such transportation is required by the public convenience and necessity. This, of course, ledright back to the extremely general congressional objectives set forth in the Declaration of Policy. The CAB also had broad authority to each to any certificate such reasonable terms, conditions, and limitations as the public interest may require, and it exercised such authority.

Certificates were often very detailed. They specified intermediate and junction points and in some cases required or prohibited stops or through services. Often, the carriage of traffic between certain pairs of cities named in a certificate, or even the carriage of certain categories of traffic, was prohibited. An important aspect of the regulatory system was that airlines could not lawfully suspend or abandon services without CAB approval.

Regulation of international routes differed from that of domestic routes. Most important, CAB decisions with respect to international route applications of both U.S. and foreign airlines were subject to the approval of the President. The Supreme Court eventually held the president's decision to be unreviewable. Also, foreign air carrier applications were generally based on pre existing intergovernmental air transport agreements that granted route rights to the airline designated by the foreign government. This alone was almost invariably considered sufficient to meet the statutory standard applicable to the grant of foreign airline route applications (that the proposed transportation will be in the public interest).

Passenger fares and cargo rates were also subject to strict regulation. Carriers were required to file formal tariffs, establishing prices charged and applicable terms and conditions. These tariffs had to be filed in advance and could be rejected (for technical reasons) or suspended (for perceived substantive problems). Fares and rates were to be just and reasonable, and discrimination (with its panoply of related legal terms such as undue or unreasonable preference or advantage, unjust discrimination, and undue or unreasonable preJudaic or disadvantage) was prohibited. Once a given tariff became effective, it had to beobserved; all forms of rebating were prohibited.

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Standards for evaluating the reasonableness of fares and rates were as general as those for awarding routes. Thus, among other factors, the CAB was to consider —the need in the publicinterest of adequate and efficient transportation of persons and property by air carriers at the lowest cost consistent with the furnishing of such service; and the need of each air carrier forrevenue sufficient to enable such air carrier, under honest, economical, and efficient management, to provide adequate and efficient air carrier service. In practice, the CAB applied public utility —rate of return on investment principles in its rate reviews and ratemaking, and all carriers generally were required to charge like amounts for like services.

As for international routes, the CAB had to share authority over international rates with foreign governments. The obvious complexities were greatly ameliorated, in practice, by broad worldwide acceptance of the International Air Transport Association (IATA) as a forum for meetings and rate agreements among international airlines, subject to approval by interested governments.

The CAB also established rates to be paid airlines by the Post Office Department for the carriage of U.S. mail, both domestic and international; this was the mechanism for providing the subsidy that all air carriers initially required. Thus, while the mail rates were to be —fair and reasonable, one of the factors to be considered was —the need of each-... carrier forcompensation for the transportation of mail sufficient to insure the performance of such service, and, together with all other revenue of the air carrier, to enable such air carrier under honest, economical, and efficient management, to maintain and continue the development ofair transportation to the extent and to the character and quality required for the commerce of the United States, the Postal Service, and the national defence. As in its commercial rate making, the CAB based subsidy allowances on —rate of return on investmentanalyses.

Although route and rate regulation had the most direct and visible impact on public service, the CAB also exercised a broad range of other economic controls over the air transportation industry. Thus, it could (and did) prescribe in detail the accounts and records to be maintained by air carriers and the reports to be submitted. Agreements between air carriers had to be filed with the CAB, whose approval was required for certain specified interlocking relationships and for air transport-related mergers, consolidations, and acquisitions of control.

At the same time, however, CAB approval of such agreements granted immunity from the general antitrust laws. The CAB also was authorized to investigate and terminate unfair or deceptive practices or unfair methods of competition in air transportation.

One further economic provision of the Civil Aeronautics Act warrants mention in light of deregulation legislation and post deregulation developments. It relates to labor relations between the airlines and their employees. In recognition of the public interest characteristics of air transportation, air carriers were required to comply with the provisions of the Railway Labor Act, which prescribed an elaborate system for resolving disputes.

The Federal Aviation Act of 1958

In 1958, President Eisenhower, citing midair collisions of aircraft that had caused several fatalities, asked Congress for legislation to establish, a system of air traffic management which will prevent within the limits of human ingenuity, a recurrence of such accidents.

Congress responded by enacting the Federal Aviation Act of 1958, which was signed into law on August 23, 1958. The new law created the Federal Aviation Agency (FAA), which was given

authority over the nation's airspace. The FAA combined the existing functions of thethat would bring market performance of reasonable quality without any economic regulation.

Despite increased criticism and occasional congressional studies that led to minor regulatory changes, it was not until 1975 that certain factors began combining for a successful push to deregulation. Traditional distrust of government regulation in general became sharply focused on air transportation through a series of economic and regulatory developments. Adversity struck the industry in 1970 when large increases in capacity, resulting from the advent of wide-body jet aircraft, coincided with a serious economic recession. This, in turn, led to widely criticized CAB regulatory policies, including a four year moratorium on all new-route cases and approval of a series of agreements among airlines to limit capacity over certain major routes. At the same time, CAB pricing policies (which set industry wide standards based on average industry costs) were increasingly viewed as fostering inefficiency, higher costs, and higher prices. Critics pointed to the experience of several intrastate carriers in California and Texas (not regulated by the CAB) that charged lower per-mile fares for comparable distances than the CAB-regulated airlines and that operated more profitably.

The storm might have passed had it not been for the Arab oil embargo of 1973 and the ensuing massive increase in fuel costs. Airline operating costs soared, while traffic decreased due to the recession. One result was a series of fare increases. However, with cost increases exceeding increases in yields, another period of poor airline earnings followed. This later factor added to the list of arguments for regulatory reform the contention that the airlines themselves would be beer off with some form of deregulation. It was in this atmosphere that two influential reports were released. One was a special CAB staff study on regulatory reform, dated July 1975. It concluded: —Protective entry control, exit control, and public utility-type price regulation under the Federal Aviation Act are not justified by the underlyingcost and demand characteristics of commercial air transportation. The industry is naturally competitive, not monopolistic. The study recommended that protective entry, exit, and public utility-type price controls in domestic air transportation be eliminated within three to five years by statutory amendment. At about this same time, an influential report was released by the Subcommittee on Administrative Practice and Procedure of the U.S. Senate Judiciary Committee, headed by Senator Edward Kennedy. The report's repeated message was that prices should and would be lower with a more competitive system. The CAB's practices, thesubcommittee report concluded, while effective in promoting industry growth, technological improvements, and reasonable industry profits, had not been effective in maintaining low prices. The report further stated that it was economically and technically possible to provideair service at significantly lower prices, bringing air travel within the reach of the average citizen. With the sudden increase in anti regulation sentiment, President Gerald Ford's administration in 1975 sponsored the first deregulation bills. This started the legislative process that culminated in the Airline Deregulation Act of 1978.

Even before the act's passage, however, the CAB had begun its own administrative journey on the road to deregulation. First, Chairman John E. Robson, who took office in 1975, gradually relaxed the moratorium on scheduled service routes of his predecessor. Supplemental (charter) airlines were given greater opportunities through the expansion of the scope of permissible charters. The CAB also permitted greater carrier flexibility to reduce fares. These initial cautious moves gained enormous momentum under Chairman Alfred E. Kahn, appointed by President Jimmy Carter in 1977. Under his vigorous leadership, the CAB soon began processing and approving applications for new operating authority, particularly when the applicants promised lower fares. To enforce compliance with such promises, CAA, the aviation functions of the secretary of commerce, the duties of the Airways Modernization Board, and the safety and regulatory functions of the CAB.

Under the new law, however, the CAB retained its jurisdiction over route allocation, accident investigation, and fare applications. The 1958 act expressly empowered the FAA administrator to regulate the use of the navigable airspace by both civilian and military aircraft, to establish air traffic rules, to conduct necessary research, and to develop air navigation facilities. The act also provided that military aircraft is exempt from air traffic rules in the event of urgent military necessity and provided for restricted airspace zones for security identification of aircraft.

The 1958 act le_ virtually unchanged the economic regulatory provisions but made several revisions to the safety program. Although the CAB retained its duties in the fields of air carrier economic regulation and aircraft accident investigation, the board's power to enactsafety rules were transferred to the administrator of the FAA, with the result that the later official promulgated the regulations and standards. The CAB's role in safety rulemaking waslimited to participation as an interested party in FAA proceedings. A second important revision of prior law concerned procedure in cases involving suspension and revocations of safety certificates. Whereas under former law only the CAB could suspend or revoke in thefirst instance, the new act provided for initial action by the administrator, subject to the certificate holder's privilege of appeal to the board.

Apart from these makers, the FAA administrator wielded essentially all the powers and duties his predecessor had under the 1938 act, plus a clearer authority to allocate the navigable airspace between military and civilian users.

In the spring of 1967, Congress created the Department of Transportation. The FAA as such was in effect abolished, and in its stead was established within the new department a FederalAviation Administration, headed by an administrator. The FAA's functions were transferred to the Department of Transportation, where, for the most part, they were placed under the Federal Aviation Administration, where they remain today. The Department of Transportation Act also transferred the CAB's accident-investigating and related safety functions to the new department and, in turn, immediately re-delegated them to a new independent agency called the National Transportation Safety Board.

The Deregulation Movement

Despite remarkable advances under the regulatory system established in 1938, as well as broad public satisfaction with the airline system, air regulation gradually came under increasing criticism, particularly from academic economists. This criticism gained strong momentum in the mid-1970s, and between 1977 and 1979, a veritable revolution was accomplished in both domestic and international U.S. air transport policy.

The infancy of the air transport industry, and then World War II, produced an initial period free from serious criticism, but the basic economic regulatory policies of the Federal Aviation Act eventually came under attack. The key issue, as might be expected, was the relative desirability of free competition in this industry versus the supposed need for tight government control of entry, exit, pricing, and other issues. As early as 1951, in a study titled *FederalControl of Entry into Air Transportation*, Lucille Keyes questioned both the theoretical and empirical bases for the regulatory system. In 1962, Richard E. Caves, in *Air Transport and ItsRegulators*, concluded that —the air transport industry hascharacteristics of market structureawards were made for short terms, with renewal dependent on performance. The CAB also was much more receptive to route realignments and elimination of restrictions, as well as to exit from those markets to which entry had been liberalized. During this same period, the Carter administration sought agreements with foreign governments to permit more international competition and was prepared to authorize as much international service by U.S. airlines as foreign governments would accept.

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There was also far greater receptivity to fare reductions. Indeed, CAB Chairman Kahn carried it to the point of justifying dismissal of a complaint against illegal rebating by stating: —The law prohibits departure from tariffs, but departures from tariffs are good for competition. Rebating as we see it is a consequence of noncompetitive rate levels, and the best theoretical remedy is to reduce fares.

The Carter administration's support for deregulation was an important factor, but the movement was also aided by improved industry profitability. Some observers attributed the industry's profitability to the CAB's new pro competition policies. However, from 1976 to 1978, the industry was merely experiencing its traditional cyclical upturn after the sharp downturn in 1975.

was, of course, substantial opposition to any significant relaxation of regulation from most airlines, from airline labour unions, and from financial institutions with investments in the industry. Their arguments covered a broad range of concerns, including these:

- 1. Possible worsening of the industry's excellent safety record
- 2. Probable concentration of service on dense traffic routes, with a consequent deterioration of service on others, especially those serving small communities
- 3. Impairment of the air transportation —system, with its conveniences of through baggage handling, interline ticketing, and so on
- 4. Destructive and predatory price competition, resulting in earnings deterioration and, ultimately, increased industry concentration
- 5. Reduced ability to re-equip and to finance otheravailable technological advance
- 6. Adverse impact on airline employees

But these arguments failed to halt the drive for deregulation. Indeed, although what finally emerged as the Airline Deregulation Act of 1978 was working its way through congressional hearings and reports and although the bills themselves were undergoing various revisions, a mini-deregulation bill was passed by Congress with little fanfare or public notice. This was the deregulation of domestic all-cargo service, which became law in November 1977. Actually, it entered the statute books buried in a package of changes attached to a bill dealing with war risk insurance.

The technique for all-cargo deregulation was simple and effective. Any airline that, under the authority of a certificate or exemption, had provided any scheduled domestic all-cargo service during 1977 could, within 45 days after passage of the law, apply for authority for any and all other domestic all-cargo service, and the CAB was directed to grant the application promptly. At any time within one year after passage, anyone could apply for a domestic all cargo certificate, which was to be granted within 180 days of application, unless the CAB found that the applicant was not —fit, willing and able. In addition, the CAB's authority to regulate domestic cargo rates, whether carried on combination or all-cargo aircraft, was limited to those cases in which the board found, after a hearing, that the rates were discriminatory, preferential, prejudicial, or predatory. The pre-existing test of —unjust orunreasonable was eliminated, and the CAB was specifically precluded from suspending proposed cargo rates pending a hearing.

In March 1978, another deregulation law dealing with cargo was passed. It gave charter airlines the same immediate opportunity to obtain certificates for scheduled all-cargo service that was made available to scheduled carriers by the 1977 law.

The Airline Deregulation Act of 1978

The Airline Deregulation Act of 1978 dealt primarily with domestic air transportation. There was still substantial practical recognition of the fact that no one government could by itself deregulate international service. As a result, Congress established a new Declaration of Policy applicable only to domestic air transportation; the pre-existing policy statement continued to apply to international air transportation.

The overriding theme of the act was competition. There was to be maximum reliance on competition to attain the objectives of efficiency, innovation, low prices, and price and service options while still providing the needed air transportation system. —Competitive market forces and —actual and potential competition were —to encourage efficient and well-managed carriers —to earn adequate profits and to attract capital. At the same time, however, Congress was responsive to small-community needs and pressures, and so the act called for —maintenance of a comprehensive and convenient system of continuous scheduled interstate and overseas airline services for small communities and for isolated areas in the United States, with direct federal assistance where appropriate.

Restrictions on entry into domestic service were to be gradually eliminated over the next several years, with complete elimination by the end of 1981 (subject to CAB determination that particular applicants were —fit, willing and able). The standard for granting route applications was immediately changed from the pre-existing requirement, that the proposed transportation —is required by the public convenience and necessity, to a finding that it—is consistent with the public convenience and necessity. Further, the burden was now on opponents to prove lack of such consistency. Several special provisions were made for the three-year interim. First, any certificated airline (scheduled or charter) had the right of entry to one new route in each of the three years before complete open entry. Second, subject to certain limitations, carriers could lay claim to unused authority of other carriers. And third, the CAB was authorized to issue experimental certificates for temporary periods.

The new law contained other entry-related provisions that liberalized the pre-existing regime, including the following:

- 1. Domestic fill-up rights on international flights. For example, an international carrier flying from Los Angeles to Rome via New York could be given authority, even though not previously possessed, to carry domestic traffic between Los Angeles and New York on at least one round-trip flight a day.
- 2. Removal of restrictions. All —closed-door restrictions contained in domestic certificates were eliminated. Thus, if an airline was authorized to fly from City A to City B to City C but prohibited from carrying traffic from B to C, that restriction was eliminated.
- 3. Suspension and reduction of service. Provisions were adopted that greatly simplified the ability of carriers to reduce or eliminate service. The CAB was also directed to establish simplified procedures for disposing of certificate applications and requests for amendment or suspension of certificates, and the board was given relatively short deadlines for reaching decisions.

The ultimate liberalization of entry occurred, as scheduled, on December 31, 1981, when the sole barrier to unrestricted domestic entry was the requirement that the applicant be fit, willing and able a finding that had already been made for all existing certificated airlines.

For all practical purposes, all airlines (and virtually all would-be airlines) are now free to serve, or to cease serving, any and all domestic routes and cities.

Congress did recognize the need to ensure continued service to communities that might otherwise have been abandoned or provided an unacceptable service level under deregulation. The traditional subsidy program for local-service carriers, which was directed more toward sustaining the carriers than to maintaining specific service to small communities, was to be phased out by the end of 1985, and a new program of subsidies to guarantee essential air transportation to specific communities was established. All cities named in any certificate are automatically eligible, and unless the city is served by at least two airlines, the CAB (or, now, the Department of Transportation, to which this responsibility was transferred) was required to determine what and how much service is —essential.

IARE	AIR TRANSPORTATION SYSTEMS
	Source from Air Transportation Systems by Mike Hirst

Essential air service at any given city is defined as scheduled service, at specific minimum frequency and at fair rates, to one or more other cities with which it has a community of interest. Whenever it is found that a city will not receive essential air transportation without subsidy inducement, applications to perform subsidized service must be sought and an award made at an established rate of compensation. Under the deregulation act, this program was to be continued until 1988; it was subsequently renewed for another 10 years.

The act specified a number of other changes affecting CAB authority over operating rights, including these:

- 1. Expanded authority to grant exemptions from economic regulatory provisions. The standard for granting exemptions was considerably eased, and, for the first time, exemptions could be granted to foreign airlines.
- 2. Specific validation for certain liberalized charter rules that were under court challenge.
- 3. Limitation of the president's authority to overrule the CAB in international route cases.

Formerly, there were no statutory standards for presidential review and no deadlines for any action. Now, the president may only disapprove such decisions for foreign policy or national defence reasons.

The act also dealt with domestic fares. Pending almost complete deregulation at the end of 1982, the general criteria for CAB consideration in exercising its rate regulation functions were amended to give more weight to the desirability of low fares and increased pricing and service options. The act also created a zone of reasonableness for domestic passenger fares geared to standard industry fare levels, which, in turn, were based on July 1, 1977, fares adjusted periodically for changes in average operating costs. Within this zone, the CAB could not suspend as unreasonable any fare as much as 50 percent lower or 5 percent higher than the standard fare. There were major changes in the antitrust area as well. Certain types of inter airline agreements, transactions, and relationships were removed from CAB jurisdiction and thussubject to federal antitrust laws. For those transactions still requiring CAB approval (such as mergers), the standard for approval more closely conformed to general antitrust principles. In addition, the previous automatic immunity from antitrust laws for any transaction or agreement approved by the CAB was repealed. The CAB was given discretionary power to grant immunity when specifically requested. Strong labor opposition to the act led to the inclusion of an employee protection program.

This program was intended to provide for preferential hiring and financial assistance to eligible airline employees who lost their jobs or suffered pay cuts because of bankruptcy or major downsizing of a carrier due to the change in regulatory structure caused by the act. Although the program was to be administered by the secretary of labor, the CAB was to determine the circumstances under which the protective provisions become operative. (The CAB never did find that any employees were entitled to protection under that statutory test.) Most dramatic of the deregulation act's provisions was the CAB's demise (sunset). On January 1, 1985, the CAB ceased to exist altogether, and its authority over subsidies and foreign air transportation was transferred to the U.S. Department of Transportation (DOT). First, however, late in 1984, Congress made some changes to the 1978 act, primarily to ensure continued consumer protection and to transfer authority over mergers and agreements to the DOT rather than to the Department of Justice.

POSTDEREGULATION EVOLUTION

With market entry opened up by deregulation, a series of major changes occurred in the industry's structure. Because the routes of greatest traffic volume and financial appeal were those originally within the trunk system, this is naturally where most exploitation of the free-entry opportunity occurred. Trunk carriers themselves moved into one another's territories, entering markets they had

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	Source from Air Transportation Systems by Mike Hirst	

previously desired but been unable to obtain. For the trunk carriers as a group, the substantial movement into one another's markets essentially represented a standoff in the sense that, while all of these carriers gained new opportunities, they also lost markets as other carriers moved into their own previous territory.

Merger Mania

In July 1979, Southern Air Lines and North Central Airlines merged to create Republic Airlines. Not content with what was basically still a regional route system, Republic purchased Hughes Airwest in November 1980 and expanded its route system to the west coast. With this merger of three local-service carriers into one major carrier, the industry consolidation phase began.

Pan American merged with National Airlines in 1980, theoretically to obtain a domestic route system. However, the real significance of this merger was not that Pan American eventually won the rights to take over National, but rather that Texas International Airlines lost. With the profits from the sale of its National Airlines stock, Texas International started New York Air in January 1981. In January 1982, the Texas Air Corporation was set up to operate New York Air. In October 1982, the Texas Air Corporation purchased Continental Airlines and combined it with Texas International. Continental continued to operate as a separate entity, but Texas International went out of existence. On a single day in December 1978, Braniff Airlines, the most aggressive former trunk carrier

pair markets. Unfortunately, it became the first victim of deregulation, forced to cease operations in May 1982. Many factors contributed to Braniff's demise, including a high debt structure, a recession-weakened demand for transportation, and dramatically higher fuel prices. Eastern Airline s subsequently acquired Banff's prized Latin American routes. In 1991, American Airlines would acquire these routes on the demise of Eastern.

Merger activity remained fairly dormant for the next couple of years, reappearing again in March 1985, when Southwest Airlines purchased Muse Air (later to be renamed Trans Star), one of its major competitors in Texas markets. However, merger actions began in earnest again in fiscal 1986.

People Express acquired Frontier Airlines during the fourth quarter of 1985 and continued its acquisitions in 1986 by purchasing Provincetown Boston Airways in January and Bri_ Airways in February. In September 1986, People Express was acquired by Texas Air Corporation. In April 1986, Texas Air had added Rocky Mountain Airways to its empire, and by September, Eastern Airlines was under its corporate umbrella.

In May 1986, Delta acquired two commuter airlines, Atlantic Southeast and Comair. By the end of the year, Delta completed the purchase of Western Airlines. In September of that same year, Trans World acquired Ozark Air Lines, while Northwest Airlines, which had acquired Mashaba Airlines in 1984, acquired Republic Airlines. Meanwhile, United acquired Pan American's Pacific routes during the year, and American acquired Air California in November 1986. Allegheny Airlines, a former local-service carrier ambitious to become a major carrier in the deregulated environment, changed its name to USAir in October 1979. By 1985, it had acquired Pennsylvania Airlines, and in April 1986, it added Suburban Airlines, followed by Pacific Southwest Airlines in December of that same year. Then, in December 1986, USAir acquired another former local-service carrier, Piedmont Airlines. Piedmont had acquired Henson Airlines in 1983, followed by Empire Airlines in 1985 and Jetstream International in July 1986.

The consolidation movement that began in 1979 has had a profound impact on the structure of the commercial airlines industry, and its effects are still being felt. Continental Airline Holdings (the

IARE	AIR TRANSPORTATION SYSTEMS
	Source from Air Transportation Systems by Mike Hirst

former Texas Air), which in the 1980s had been taken into and out of bankruptcy by its former owner, Frank Lorenzo, wound up in bankruptcy once again in 1990, when its overleveraged balance sheet proved too heavy a burden in a time of high fuel costs and a recessionary economy.

Fi_y-three years of aviation history came to an end in January 1991 when Eastern Airlines, tothe surprise of few in the industry, finally ceased operations after a lengthy struggle for survival. Incorporated in 1938, Eastern was one of the nation's original four trunk airlines. Plagued by labor problems and operating under Chapter 11 bankruptcy since March 1989, Eastern was pushed over the brink by the outbreak of the Persian Gulf War, which resulted in rising fuel costs and decline in travel during the recessionary early 1990s.

In April-1991, American Airlines acquired Easter no's routes to 20 destinations in 15 Central and South American countries, and in December of that year, it struck deals for Continental's Searle–Tokyo route authority and for TWA's remaining U.S.–London routes. American had already purchased TWA's Chicago–London route in 1989. By the end of 1991, anotheraviation pioneer went out of business: Pan American, whose history traced back to 1927, when it began flying the mail between the Florida Keys and Havana. Later, it pioneered transpacific service with its flying boats, and it was the first carrier to fly both the Boeing 707

and 747. Its financial problems began in earnest with the acquisition of National Airlines shortly after deregulation. In 1991, Delta solidified its position in the ranks of the —big three carriers by acquiring first the Pan American Shuttle and later the bulk of Pan American's transatlantic and European systems. The Delta Shuttle began operating between Boston, New York, and Washington, D.C., in September 1991. Competition on the shuttle route stepped up a notch when USAir took over operation of the Trump (formerly Eastern) Shuttle. Meanwhile, in the early 1990s, United Airlines acquired first Pan American's Latin American routes and then Pan American's London routes. In 1991, United also completed the purchase of its primary United Express partner, Air Wisconsin, rescuing that carrier from potential bankruptcy.

In January 1992, TWA went into Chapter 11 bankruptcy. In its filing, TWA listed assets of \$2.7 billion and liabilities of \$3.5 billion. Subsequently, it sold its London routes from Philadelphia and Baltimore to USAir. Earlier, it had sold the bulk of its London routes to American. The Persian Gulf War and a recessionary economy contributed to the addition of America West in 1991 to the list of bankrupt U.S. carriers. Another new-entrant carrier since deregulation, America West became a major airline in 1990 acer rising from regional to national status. The fish-largest carrier, Northwest, also was in financial difficulty by early 1992 due to its leveraged buyout in 1989. Northwest's problems affected another new entrant carrier born in the deregulation era: Midway Airlines. One of the few remaining new entrants during the deregulation era and the purchaser of Air Florida, Midway went out of business in November 1991 when northwest backed out of an agreement to acquire the carrier. Founded in 1979, Midway grew into a national carrier by 1990. Two true success stories during the deregulation period have been Federal Express and Southwest Airlines. Both carriers were founded in the early 1970s and have been consistently profitable over the years. In the late 1990s and early 2000s, new types of air carriers emerged as a result of obscuring strategies by the major airlines, expansion of niche markets, and competitive forces. Recent trends indicate that four types of air carriers are growing: new-entrant/ low-cost, regional/feeder, mega-carrier, and virtual carrier. New-entrant carriers include airlines such as Spirit and JetBlue. Regional/feeder carriers continue to expand as major airlines realize the benefit of feeder traffic to the main hub airports. Mega-carriers are forming as major airlines partner up with other major airlines in order to reduce costs and increase market share. Because of the high costs of launching a new airline, more virtual carriers exist than ever before. Such carriers subcontract most of their services out to other companies, therefore reducing investment risk.

Regional/Commuter Airlines

Spurred by deregulation, many regional/commuter airlines entered the market in the early 1980s. Simultaneously, the major carriers sought to extend their high-density markets by increasingly dominating their hub airports and sloughing off less profitable routes. The hub system, which has proliferated since deregulation, establishes a number of routes connected to a central hub airport where passengers are collected from feeder flights, transferred to other flights on the same line, and are then carried to their ultimate destination. This trend encouraged regional airlines to offer service linking small cities and providing connections to hub airports. Flying primarily turboprop aircraft and requiring less ground -based infrastructure, the regional airlines could operate such routes more profitably than the major carriers and provide a needed service.

In 1985, there was a dramatic growth in the number of code -sharing agreements between regional airlines and the major carriers. These code- sharing agreements varied from partial or built in component form, with only the final assembly taking place at the parent company'splant. In the case of the MD- 11, the wings were built in Canada, the winglets were produced by Italy's Anthelia, the tail cone came from Mitsubishi, and the control surfaces were manufactured by companies such as Embraer and CASA.

Boeing, seeking to close the gap between the 767 and 747, developed the 777, an even larger twinengine airliner capable of carrying 305–440 passengers. Powered by huge General Electric, Pra_ & Whitney, or Rolls-Royce fan-jet engines in the 74,000- to 92,000- pound- thrust class, with fan diameters approaching 10 feet, the 777 offers efficiency, size, and long-range capability. One of the 777's unique options is its folding wing tips, which reduce the 200-foot wingspan to less than 160 feet for simplified docking at crowded gates.

It should be noted that in 1997, Boeing and McDonnell-Douglas merged to become one company, leaving Airbus Industry as the primary competitor. The merger was a strategic move to expand Boeing's presence in the increasingly competitive aircraft manufacturing

market. The merger was anticipated to bring an estimated \$48 billion in revenues per year. After the merger, Boeing moved its corporate headquarters from Seattle to Chicago. In 2006, Boeing and Airbus continue to remain the largest aircraft manufacturers in the world constantly competing to outperform the other in terms of sales. New aircraft technology leads to increased sales and for the first time since 2000, Boeing is once again the number one aircraft manufacturer leaving Airbus in the number two position. Boeing's production of the B787 Dreamliner has captured the industry by storm as airlines strive toward operating fuel efficient twin-engine aircraft on long-haul flights. However, circumstances could change at any time as Airbus markets new aircraft like the Airbus A380, the world's largest commercial aircraft, and the A350 to compete against the Dreamliner.

On September 11, 2001, the world was shocked to hear about the biggest disaster in the history of aviation. Four commercial airline flights were hacked simultaneously (United Airlines Flight 93, Newark to San Francisco; American Airlines Flight 77, Washington Dulles to Los Angeles; United Airlines Flight 11, Boston to Los Angeles; and American Airlines Flight 175, Boston to Los Angeles) . Flight 93 missed its intended target, believed to be the White House, and crashed into a field in Somerset, Pennsylvania, killing all 45 persons on board. Flight 77 was flown directly into the Pentagon, the citadel of world strategic military planning, killing 189 persons. Flight 11 was flown directly into the north tower of the World Trade Centre in New York City, killing all 92 persons on board the aircraft. Flight 175 was flown directly into the south tower of the World Trade Centre, killing all 65 persons on board. In the end, more than 3,000 people lost their lives on 9/11 as a result of the acts of fanatic terrorists.

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Because of the events of 9/11, security at airports, as well as security at high-risk events outside aviation, was stepped up significantly. The global aviation business was hit hard financially and continues to recover. It was estimated in October 2002 that airlines in the United States would lose a total of \$8 billion by the end of the fourth quarter for the same year. Some analysts said that these estimated losses were optimistic and that \$10 billion would be a more likely figure.

Since the events of 9/11, a number of airlines around the world have declared bankruptcy with some closing their doors forever. In this new era of air transportation, air carriers haveoutright ownership to pure marketing alliances devoid of any ownership by the major carriers. A somewhat predictable outgrowth of these agreements has been the identification of commuter partners with the business name of the major airline partner. Just as in the contract experiments with local airlines in the late 1960s, many independent commuter airlines conduct operations under a —service mark similar to that of their major carrier partners. Thus, commuter airlines bearing such names as Continental Express, United Express, American Eagle, and Northwest Airline are flying the skies. The evolution of the relationships with the large air carriers has led to further route rationalization policies on the part of the larger partners. The result has been a process of industry consolidation, increasing concentration, integration, and transition to jet equipment.

From a high of 246 carriers in 1981, the number of regional/commuter operators declined to 124 in 1995. As of year-end 2004, there were 74 such operators in business carrying a total of 134.7 million passengers. Although the number of carriers in this market shows a steady decrease, the number of passengers carried shows a steady increase. Interestingly, the number of hours flown on an annual basis is gradually increasing indicating that regional/commuter operators, although decreasing in number, are becoming larger in size resulting in increased market share, longer flights and better utilization of aircraft. Because of the increasedintegration of operations with the large air carriers (through code -sharing agreements and partial or total acquisition of the regional's) the success of many regional airlines is closely tied to the success of their larger partners.

Although the number of carriers has declined overall, the size of the dominant carriers has risen dramatically. This has resulted in increased industry concentration, with the top 50 carriers accounting for approximately 98 percent of the total passenger enplanements andrevenue passenger miles. When we look at the corporate structure, the picture of industry concentration becomes even clearer. In 1995, 36 of the nation's top 50 regional air carriersused the two-letter designation code of a larger carrier to list their flights. In total, there were 46 code-sharing agreements in existence as of June 1996. These relationships varied from outright ownership by the larger carrier (11 airlines), to partial ownership (4 carriers), to pure marketing alliances (31 carriers). More sophisticated, modern aircraft are added to the regional airline fleet each year. The average trip length for the regional airline passenger has increased, as has the transition from piston to turboprop and jet equipment. As of January 2005, the number of regional air carriers operating at U.S.-airports was extensive. Table 2-4 provides a breakdown of airport use by state including regional and non-regional operations.

New-Generation Airliners

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In the early 1980s, after years of flying the once-revolutionary Boeing 727, 737, and 747 and the McDonnell-Douglas DC-8, DC-9, and DC-10, the airlines were ready for newer, more efficient designs, not simply retooled versions of the old ones. If the two dominant .S. airframe manufacturers would not supply them, foreign sources, notably the Airbus Industries consortium from Europe, would

AIR TRANSPORTATION SYST	EMS
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oblige. After all, the U.S. commuter airline industry had been dormant during the 1970s, losing market share to firms such as British Aerospace, Embraer of Brazil, Dornier of Germany, and ATR of Italy.

To hold its market share, Boeing introduced two new airliners, the 757 and the 767, certificated in October 1984 after a development process that may have cost as much as \$3billion. Both were giant twin-engine airplanes with underwing power plants supplied by GE/Snecma, par_ & Whitney, or Rolls-Royce. Flown by two-person crews, they could carry 10persons in the narrow-body 757 version or 230 in the wide-body 767. The new planes filled the niche between the 115–145-seat 737 and the smallest 420-seat 747. The 757 quickly supplanted the aging 727 with its greater efficiency, and the roomy 767 proved to be economical on the transatlantic routes.

With the increasing reliability of modern jet engines, the FAA had approved extended twin-engine operations (ETOPS) over routes that did not meet the FAR 121.161(a) requirement for continuous availability of a landing site within one hour of single-engine cruising. Historically the province of three-engine DC-10s and L-1011s as well as four engine Boeing and Douglas airliners, the new 120-minute ETOPS exemption allowed the 767 to fly to Europe without deviating over an uneconomic northern route to stay near land.

First approved in February 1985 for TWA's Boeing 767-200, the basic criteria for ETOPS was a documented in-flight engine shutdown rate of less than 0.05 per 1,000 hours of operation, or less than 1 shutdown per 20,000 hours. Given that mature turbine power plants were experiencing shutdown rates as low as 0.02 per 1,000 hours, the risk assumed by flying over routes that would require two or even three hours of single-engine cruising to reach a diversionary airport was quite small. Within eight years, ETOPS had become so commonplace that 400-seat twin-engine airliners, such as the Airbus A330 and Boeing 777, were being developed for the North Atlantic run.

Meanwhile, the 737 became the most-built jetliner in 1987, surpassing the 727's previous record of 1,832. More than 3,000 of the 737s have been sold to date, and the 300- series, introduced in 1981, began a new cycle for this phenomenally successful aircraft. The 737-300, -400, and -500 are all equipped with new-technology GE/Sencha CFM-56 turbofans and —glass cockpits with electronic flight instrumentation (EFIS) replacing the old mechanical flight directors and engine gauges. EFIS had been introduced previously on the 757 and 767.The 747-400 appeared in 1988 with an extended upper deck, bringing the total seating up to 660 in the all-tourist configuration (550 on the main deck and 110 on the upper deck, 65 more than the 200B). Featuring par_ & Whitney PW 4000, General Electric CF6-80C2, or Rolls-Royce RB 211- 524D4D engines, the 747-400 is capable of flying 7,200 miles, 1,000 more than the 747-300.

McDonnell-Douglas was able to remain a presence in the airliner business during the 1980s and 1990s, but with stiff competition from Boeing and Airbus, it saw its market share drop to 10 percent by the mid-1990s. The stretched DC-9-80 became known as the MD-80, subsequently growing into the MD-81, MD-82, MD-83, MD-87, and MD-88, with each model differing chiefly in gross weight and wing size. An MD-90 version with further updating was rolled out in February 1993. Glass cockpits became the norm, along with flight management systems that choreographed flights for maximum efficiency. The last DC-10 came off the production line in 1989, and in January 1990, the MD-11 made its maiden flight. Powered by new engines, the new airliner grosses over 600,000 pounds at takeoff and can carry over 400 passengers. The panel features six 8-inch cathode-ray tube displays, replacing all the mechanical gauges of the DC-10, and with the aid of flight management computers, the plane is simpler to fly, even with two pilots. The MD-11 offers the option of manual cable controls when the autopilot is not engaged, rather than the full fly-by-wire systems popularized

by the Airbus A320. By the early 1990s, more and more airliners were beingbeen forced to implement cost-cutting strategies in order to survive. Such strategies are discussed in later chapters

GENERAL AVIATION

World War I ended in November 1918, and several thousand Curtis Jennies, which cost the U.S. government close to \$17,000 apiece, became surplus and sold for as much as \$750 for a new plane with an OX-5 engine and as little as \$50 for a used one. Although most World War I pilots returned to other professions, a group of them with flying in their blood became barnstormers. Living from hand to mouth and acting as their own mechanics, the members of this happy- go-lucky group put on air shows and took the local town folk for rides, usually for about five minutes, and charged whatever the traffic would bear. With the passage of the Air Commerce Act in 1926 and its requirements for the licensing of pilots, maintenance requirements, and other regulations, the barnstormer era came to an end. A number of these colourful individuals settled down and became known as fixed base operators, providing everything from flight instruction, to sale of aircraft and fuel, to maintenance work. General aviation had been born.

The Home of General Aviation

Wichita, Kansas, was a boom town in the 1920s. Since its founding in 1870, the city had ridden the boom-to-bust roller coaster in cable and oil. Aviation, however, was the boom that would last. Wichita had the right terrain—flat (the city was called the world's largest natural airport). It had the right weather—clear. It also seemed to attract the right people. May Laird and Jake Moellendick began work in April 1920 on the first Laird Swallow aircraft. They soon hired three other aviation enthusiasts, who in time developed their own companies: Buck Weaver, who started Weaver Aircraft Company (WACO); Lloyd Steadman; and Walter Beech. The last two, along with another barnstormer by the name of Clyde Cessna, pooled their talents in 1925 to form the Travel Air Manufacturing Company.

The first Travel Air plane, built of welded metal tubing, as opposed to wood framing, won the 1925 Ford Reliability Tour with Walter Beech at the controls. In the 1926 Reliability Tour, Beech flew a Travel Air 4000 monoplane equipped with instruments that permitted blind flying, the first time such a feat had ever been attempted. By 1929, when the company was bought by Curtiss -Wright Corporation, Travel Air was producing 25 percent of all commercial aircraft in the United States. Beech, who worked for Curtiss- Wright until 1932, then embarked on what proved to be his greatest challenge, the start of Beech Aircraft Corporation. He soon announced plans to build a four-place cabin biplane that would fly 200 miles per hour. Impossible—or so the critics thought. Two months after Beech Aircraft introduced its first airplane, the stagger-wing Model 17, the sleek biplane flew off with first place in the prestigious Texaco Trophy Race in Miami. A string of triumphs followed as Beechcra_s won five major races in 1936 alone, including the Denver Mile-High Air Race and the Bendix Transcontinental Speed Dash. Beechcra_s continued to pick up trophies into the next decade. In 1937, the Model 18 Twin Beech was born. Employment peaked during the World War II years, and in 1946, Beech introduced the V-tail Bonanza, which has had the longest production record of any general aviation aircraft.

By 1934, economic conditions had improved sufficiently to allow Clyde Cessna to open his own small factory in Wichita and to install his nephew, Dawne Wallace, a recent aeronautical engineering graduate, as plant manager. Wallace was not paid a salary, but he did have the opportunity to design, build, test, fly, sell, and race the company's products. Wallace setabout designing the C-34, a highwing, four- place cabin monoplane with a 145-hp Warner Super -Scarab engine. After months of anxious flight tests and tedious refinements, the C- 34 was entered in the 1935 Detroit News Trophy

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Race, part of the prestigious National Air Races. The C-34 won the day, and the attendant publicity vastly enhanced Cessna's reputation as a builder of fast, efficient aircraft. Wallace's next project was a light, inexpensive trainer-utility airplane that was easy to fly and not too sophisticated to build. By 1939, the T-50 was flying, and by 1940, it was in production and ready for buyers. Among the first was the Canadian government, followed by the U.S. Army Air Corps. By 1945, some 5,000 of these trainers had been produced. A_er the war, Cessna introduced the 120/140 series, which was followed by the 190/195 series. These strong but simple single-engine aircraft helped Cessna survive the Post war shakeout of many small manufacturers of general aviation aircraft and helped propel the company into the 1950s.

Wichita is the home of another man whose name is famous in corporate aviation: William Lear, gambler, inventor, discoverer, promoter, and industrialist, who developed the highly successful corporate Lear jet.

Mr. Piper and His Cubs

At 48 years of age, William T. Piper was a successful Pennsylvania oilman when he invested in the Taylor Aircraft Company in 1931. He was a superb salesman with a clear idea of what would make a light aircraft successful. His formula was simple: build easy to- fly machines and price them low enough to attract buyers. After an abortive attempt to design a glider, Taylor Aircraft developed the E-2 Cub, an excellent example of Piper's vision of the simple airplane. The name of the company was changed to Piper Aircraft Corporation in 1936, and the subsequent models were called J-2 and J-3. The PA-11 came next in the Cub line, and then the PA-18 Super Cub, which had essentially the same structural and aerodynamic configuration as the 1932 E-2. To this day, more than one-third of the over 120,000 aircraft produced by Piper since 1937 have been Cubs, and 80 percent of U.S. pilots in World War II received their initial training in that two-place tandem design. Piper Aircraft Corporation boomed and then nearly busted during the difficult days after World War II.

The Post-World War II Years

The Aircraft Owners and Pilots Association (AOPA) had 22,000 members by the mid - 1940s (387,000 members as of 2002), and their motivations were the same then as now: to protect private flying from the depredations of the airlines and the assaults of bureaucrats who want to build empires around the commercial airlines and legislate the private flier out of the skies. The AOPA is the largest, most influential aviation association in the world. The term *generalaviation* was coined to remove the imaginedonus of the term —private flying from the industry. General aviation denotes aviation used for vital, useful, general purposes, much like those for which the private automobile is used.

The light-aircraft manufacturers, with few exceptions, envisioned their products becoming as popular as the automobile in the years to come. After a banner year in 1946, the manufacturers realized that the general public had perhaps been oversold on light plane flying and that they could not hope to have a mass-production industry comparable to the auto industry.

In 1947, a year before Cessna introduced its 170, which eventually developed into the 172, the world's most successful light plane, the industry was beginning to flounder. With manufacturing companies turning belly up all over the place, delivery ramps were clogged with unsold airplanes. At the end of 1947, sales were down 44 percent from 1946, and the downward trend continued well into 1949. But this period also represented a major turning point for the light-aircraft manufacturers, as executives began to look at the future from a different angle. The future lay in developing a fleet of airplanes that would provide solid, comfortable, reliable business transportation—aircraft that could operate in instrument conditions with high enough speed and long enough range. A certain number of

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training airplanes would have to be built to get new people started flying, but a utility airplane that businesspeople could afford and on which the manufacturer could make a fair profit was the target design for the future. production in 1951 was only 2,477 units. General aviation continued to limp along, although the ranks of the manufacturers were decimated. Beech, Bellanca, Cessna, Piper, and Ryan were still trickling airplanes off the production lines, but not all of these companies were sure that they could hang on much longer. Things were not all bad in the early 1950s: more ground-based navigation stations were built, improved static-free radios were installed, and factory options on more and more airplanes became available. Bill Lear produced the first light -plane three -axis autopilot in 1951 and made cross-country flying easier and more relaxing. Toward the end of the year, about the time that Ryan was dropping the production of the Navion, a new company, Aero Design and Engineering, offered its five-place Aero Commander to the business community; and Mooney unveiled its single-place \$1,000 Mooney Mite. That same year, Piper put a nose wheel on its little Pacer and renamed it the Tri-Pacer, which sparked a new surge of interest in light planes for fun as well as for business. By 1953, things were starting to turn around for the industry. Engineers in Wichita and Lock Haven made careful note of the growing acceptance of light twins for business. Cessna discontinued the 195 model in 1953 and produced the four-place 180, a more powerful successor to the successful 170. Piper stayed with the Tri-Pacer and the Super Cub, and Beech was backlogged with orders for the Bonanza, the Twin-Bonanza, and the Super-18. The National Business Aircraft Association held its first meeting, in St. Louis, which was attended by 9 manufacturers and suppliers along with 50 voting members and 16 associates (the annual NBAA meeting today attracts over 10,000). In 1954, Cessna and Piper introduced their four-place light twins, the 310 and the Apache, both of which represented the beginning of a long line of descendants. Many companies had entered the avionics business, including ARC, Bendix, Collins, Lear, Mitchell, and Wilcox, to name a few. Month a_er month, new autopilots were coming out for light planes.

The Maturing of General Aviation

As the 1950s turned into the 1960s, general aviation was developing an unmistakable stability and purpose. Though pleasure flying was far from extinct, the general aviation airplane clearly was developing into a viable means of business transportation. In 10 years, the general aviation fleet had more than doubled to 60,000 aircraft, over half of which were equipped for instrument flying. General aviation had become a major part of the nation's transportation system, with an inventory of light aircraft that were fully capable of flying people in comfort 1,500 miles in one day to thousands of places not served by the commercial air carriers.

Beech brought out the Travel Air, to be followed by the Baron, the Queen Air, and the King Air. Cessna put tricycle landing gear on its 170s and 180s in developing the 172 and 182 series, which became the best-selling airplanes in history. Piper discontinued the Tri- Pacer and entered the Cherokee, Comanche, and Twin Comanche into the market. Many of the old names, such as Ballance, Mooney, Navion, and North American, would also enjoy a comeback. By 1965, the general aviation aircraft fleet had grown to 95,000 airplanes, andproduction that year totalled 11,852 new aircraft. The following year a record 15,768 units were produced. General aviation growth during the late 1960s paralleled growth in the economy and all segments of aviation at that time.

Nothing added more to the growing importance of general aviation than the advent of turbine power. The business jet and turboprop were introduced to corporate users. At first, there were just a few Lockheed JetStar's, North American Superliners, Beech King Airs, and Grumman Gulfstream. It wasn't long before Bill Lear arrived in Wichita with the idea of turning a small Swiss fighter aircraft into a business jet. Both the Superliner and the JetStar were designed as military utility aircraft. Lear would go on to sell hundreds of Learjet's and, like Piper and his Cubs, his name would become

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synonymous with a certain kind of transportation. In 1970, the manufacturers of light aircraft established a strong and effective lobbying and public relations organization in Washington, the General Aviation Manufacturers Association (GAMA) . The National Business Aircraft Association (NBAA) blossomed into a highly professional Washington-based service organization for business users. The Aircraft Owners and Pilots Association (AOPA) and other special-aircraft-use organizations developed into effective lobbying groups. The Federal Aviation Administration (FAA), under administrator Jack Shaffer, appointed a deputy administrator for general aviation. Despite an economic recession during the first two years of the 1970s and an oil embargo in 1973, general aviation continued to grow, reaching a high point in 1978, with 17,811 units produced. By the late 1970s, both manufacturers and users began to feel a confidence in general aviation that they had seldom enjoyed before. Perhaps for the first time, the general aviation community perceived that potential problems related to government controls, charges, fees, and taxes, as well as restrictive legislation, were manageable. However, fundamental changes were taking place in the industry. Fuel prices rose dramatically during the 1970s, and manufacturers looked to more fuel-efficient aircraft for the future. Airspace congestion was another problem that the industry had been studying since the mid-1960s. As a result, the Airport and Airways Development Act of 1970 was passed to provide the revenue needed to expand and improve the airport and airway system

over a 10-year period. Finally, the industry was faced with ever-increasing federal regulation during the 1970s. Terminal control areas (TCAs) were introduced around the country's busiest airports, which required two-way communication with air traffic control (ATC), VHF Omni directional Range (VOR) navigation capability, and altitude-reporting transponders. Increasing regulations particularly affected the personal-pleasure pilot. It was also during the 1970s that the attention of the general aviation industry started focusing on product liability. As the number of lawsuits and the size of awards increased, insurance premiums shot up, from \$51 per new airplane in 1962 to \$2,111 in 1972. This trend was a sign of things to come for aircraft manufacturers and, no doubt, one of the major causes of the precipitous decline in the production of general aviation aircraft during the 1980s.

Unfortunately, the 1980s brought on a new round of challenges for the industry. Soaring interest rates and a depressed economy during the early 1980s had an effect on sales. Aircraft shipments dropped from 11,877 in 1980 to 9,457 in 1981 and to 4,266 in 1982. By 1994, the number had reached a record low of 928 units. Once again, the ranks of the manufacturers were being thinned. Raytheon Company acquired Beech in 1980, and in 1984, Lear-Siegler took over Piper as part of a buyout of Bangor Punta, its former parent. Piper changed ownership several more times before the end of the decade. General Dynamics took over Cessna, the last independent of the —big three manufacturers of general aviationaircraft. By 1986, Cessna decided to drop its piston-aircraft production.

Low unit sales of general aviation aircraft during the 1980s and early 1990s have been attributed to the ever-increasing cost of new aircraft with relatively few design changes sincethe 1970s, higher fuel and other operating expenses, including maintenance and hangar charges, and the availability of used aircraft. Other analysts cite product liability costs and changing tastes and preferences among the traditional business and pleasure aircraft users. Interests in sports cars and boats, the operation of which requires less training, seemed to peak during the 1980s. Another financial pressure working against aircraft ownership involved the passage of the Tax Reform Act of 1986, which eliminated the 10 percent investment tax credit (ITC). Finally, foreign aircraft manufacturers entered the traditionally U.S.-dominated market in a much bigger way during the 1980s. Although the U.S. economy experienced impressive growth and interest rates declined during the latter part of the 1980s, general aviation failed to recover. By 1992, the number of general aviation aircraft manufactured in the United States had dropped below 1,000 for the first time since the end of World War II. Between 1978 and 1994, flying hours declined by about 45 percent, and the active general

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aviation fleet, after reaching a peak of 220,943 aircraft in 1984, fell to 170,660 by 1994. More importantly for the future growth of the industry, the number of student and private pilot certificates issued dropped by almost 50 percent between 1978 and 1994. General Dynamics apparently found the field of general aviation to be too far removed from its core military business, which was in decline during the post–Cold War period, so Cessna was sold to Textron in 1992. This caused much speculation in general aviation circles about a return to light-plane production, because Textron also owned the manufacturer of Lycoming engines, which had been used in Cessna's 152, 172, 172 RG, T182, and 182 RG models, and

it would be logical to create a market for them. However, Textron also owned Bell Helicopter, and there was about as much chance of Cessna switching over to helicopter production as to start building Lycoming-powered light planes again. Cessna was satisfied building Caravan single-engine turboprops, operated primarily under contract to Federal Express over small-parcel freight routes. Cessna was also content with its line of six business jets, ranging from the 10,400 pound Citation Jet, powered by FJ44 fan jets from Williams Research, to the speedy, 31,000 pound Citation X with its two huge Allison GMA 3007C engines. More than 2,000 Citations have been sold since September 1972, when the first one was delivered; plane number 2,000, a Citation VII, was rolled out on March 30, 1993. Piper limped along through the downturn of the 1980s but still celebrated its fiftieth anniversary in 1987. However, a series of ownership changes had le it ill-equipped to make the tough managerial decisions needed in hard times. In 1970, control passed from the Piper family to Bangor Punta Corporation, itself acquired by Lear-Siegler in 1984. In turn, Lear-Siegler was taken over by investment bankers Forstmann Little in the mid - 1980s. Then, with shutdown imminent, private entrepreneur M. Stuart Millar bought Piper in May-1987 with the idea of returning it to ownermanagement. Piper dropped its product liability insurance in an attempt to discourage lawsuits, prices were cut, and enthusiasm ran high. Unfortunately, the company sipped into Chapter 11 bankruptcy in 1991, unable to build airplanes cheaply enough to fill the large backlog of orders taken at bargain prices. It was purchased in April 1992 by another entrepreneur, A. Stone Douglas. A trickle of airplanes continued to flow from the production lines under the protection of the court. Finally, in July 1995, the New Piper Aircraft Corporation was formed from the assets sale of Piper Aircraft Corporation.

Beech survived by concentrating on its traditional role as a supplier of business airplanes. With over 90 percent of the executive turboprop market firmly in the hands of the various King Airs, ranging from the 7-passenger King Air C-90B to a 10-passenger Super King Air 350, only limited plant space was devoted to piston-aircraft production. However, Beech still offered its four-place Bonanza F-33A, a six-seat Bonanza A-36 or turbo-charged B36TC, and a twin-engine Baron 58. These finely crafted, piston-powered planes served to introduce future King Air buyers to Beech quality. Beech acquired the rights to Mitsubishi's Diamond business jet in 1986, giving it a fast entry into the business jet field, just above the largestKing Air. This was actually Beech's third attempt at jets. The company had entered into marketing agreements for the Frenchmade Moraine-Saulnier MS-760 in 1955 and the British-made Hawker BH-125 in the 1970s, but neither venture had been overly profitable. This time, however, Beech was in a position to take over the production of its jets, which it redesigned and built as the Beech Jet-400A.

The rest of the U.S. general aviation industry held on through the 1990s by staying small, merging, or diversifying. Mooney had been owned by the French firm Euralair since 1984 and was still building single-engine aircraft in the Kerrville, Texas, plant it occupied in 1953. Learjet was sold to the Canadian firm Bombardier, but it remained based in Wichita. The stretched Model 55 grew into the Model 60, certificated in late 1992. Specialty aircraft builders hung on by exploiting their particular niche, such as manufacturers of fabric-covered tail-wheel airplanes (Husky, Maule, Talocrural_,

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American Champion), amphibian flyingboats (Lake), custom-made and steel-tube classic aircraft (Ballance, Waco Classic), and other personal airplanes (Commander's 114 B and the American General Tiger, a rebirth of the Grumman AA-58). Signs of optimism appeared in 1994 with the passage of the General Aviation Revitalization Act, which limited products liability suits, and with Cessna's announcement that it would resume production of single-engine aircraft in 1996. The New Piper Aircraft Corporation was formed, and in 1995, general aviation aircraft shipments finally increased after an 18-year decline. Unquestionably, the 1990s brought new challenges to the industry. But as the history of general aviation shows, this is hardly a novel situation.

Business Aviation

Although business or corporate flying had its foundations in the 1930s, when petroleum companies, newspaper publishers, and manufacturers owned and operated their own aircraft wasn't until the late 1950s that business flying really took off. The turbine engine was one of the major factors. Ever since the end of World War II, corporate operators had reliedheavily on former military aircraft that were converted to civilian use. The Lockheed Lodestar and Ventura were examples. Pacific Air motive Corporation's Lode-star conversion ,the Lear star, was one of the most sought after of its kind. It offered 280-mph speed and 3,800- mile range. The DC-3 and its version, the C -47, fit well into the corporate fleets. Many corporate flight departments operating today got started with Beech D-18s or E-18s, each powered by 450-hp par_ & Whitney R985 radial engines.

But the end was signaled for the large radial-engine business aircraft with Grumman Aircraft corporation announcement in 1957 that it intended to build the first made-for business- aviation turbine-powered airplane. It would be called the Gulfstream, and it would cost a half-million dollars.

Lockheed was first on the turbojet scene with its JetStar, but the big winner in the jet competition was North American Aviation T-39 Superliner. The DH-125 twin-jet airplane by DE Havilland followed, and a short time later, Dassault of France was ready with its Model-20 Falcon. By the mid- 1960s, turboprops abounded. The Turbo Commander and King Air could be seen on many ramps, and there was talk of the coming of the Mitsubishi MU-2. But perhaps the favored aircraft among Fortune 500 companies was the Beechjet. Business and corporate aviation has been less severely affected than other segments of general aviation, a fact that reflects the reliability and flexibility of today's corporate fleet.

Deregulation has had a twofold effect on general aviation. First, corporations and businesses with widely scattered plants, mines, mills, construction sites, and soon have found it essentialto establish flight departments equipped with high-performance aircraft to minimize executive trip time, increase employee productivity, and maintain a high level of cohesion and control of far-flung operations. Second, the proliferation of hub-and spoke operations for commercial traffic has expanded scheduled regional and commuter airline systems, which feed about 70 percent of their passengers from widely scattered, low-density airports into large, high-density terminals, where they can continue their trips on the major carriers. The regional/commuter airlines serve many communities in the continental United States, providing air links to communities that might otherwise be cut off from fast, efficient air transportation.

However, the proliferation and expansion of the new regional carriers does not mean that all business and corporate requirements for efficient, non-scheduled air transportation have been met. The current hub-and-spoke pattern may be economically more efficient than the elaborate multipoint network it replaced, but some passengers must pay for this in time-consuming layovers and other inconveniences during their trips. For business and executive travelers, time is of great importance—a commodity companies have shown themselves willing to pay for through the purchase of business aircraft.

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Will New Technology Affect the Future of Corporate Aviation?

It was not too long ago that the main function of corporate aircraft was to transport executives between destinations regardless of the financial cost factors. Often, the aircraft was not flown enough in a year to make it a viable mode of transport for the organization, because its use was limited to a small number of key people. Today, organizations must reduce costs wherever possible in order to remain competitive in the global marketplace. For the most part, the days of the —royal barge have disappeared as corporate aircraft operators have learned about the high costs of operating such aircraft. More and more, corporate aircraft are used not just by key executives but by employees of all levels within an organization. Some organizations continue to underutilize aircraft but there might be advantages to doing this, depending on what kind of business is transacted on board the aircraft or at a destination.

Other organizations fully utilize corporate aircraft and use this technology as a shale between destinations while maximizing the load factor. Aircraft technology has —shrunk the world, and it is becoming more important to be able to visit more destinations within a short period of time. As the need for travel increases, expenses increase. Locations that were previously not accessible by commercial and corporate aircraft need to be accessed.

New technology is being developed by government, industry, and academic partners for a type of aircraft that can safely and affordably move people and goods among underutilized airports in urban, suburban, and rural locations throughout the United States. This new technology is known as the Small Aircraft Transportation System (SATS). The project reached its conclusion with a proof-of-concept demonstration in June 2005 at Danville, VA. Demonstrations are intended to show policymakers and the public that this new technology can work. Under SATS, each aircraft will hold 4 to 10 people, including the pilot(s). Each aircraft will be outfitted with digital avionics suites with satellite-based navigation systems, onboard computers that permit coordinated control and display of aircraft system operation and status, and synthetic vision that allows operations in low-visibility environments. A computer display will show a three-dimensional view of the flight path, terrain, obstacles, traffic, and weather, with superimposed guides for the pilot to fly any flight plan selected. These aircraft will have simpler controls than any aircraft currently flying, making the aircraft easier to operate. The conventional throttle and mixture controls will be replaced by a single lever power control. The yoke and pedals will be replaced by a simple joystick control.

Because of the simplicity of this technology, the amount of flight training required will be reduced, and techniques used will be simplified. It is expected that a person will receive private pilot certification with instrument rating in an economical and accelerated single course. SATS aircraft will have access to the Internet and the Public Switched Network for airborne communications. Each aircraft will also have access to weather graphics, traffic information, and ground facility information, allowing operators to schedule reservations for meetings, accommodations, car rentals, and restaurants while in route.

SATS aircraft will not be dependent on current air traffic control (ATC) systems because of the use of satellite-based navigation information. Each aircraft will know its exact location from takeoff to landing, reducing the number of delays currently imposed by ATC systems.

For corporate operators, this will mean a more efficient environment to conduct business. Each SATS aircraft will —beam its location and intent to other SATS aircraft in the vicinity and to local ATC facilities, reducing routing and scheduling constraints. Once SATS matures, it will integrate with the National Airspace System. It has been determined that approximately 5,000 existing SATS Portal Airports throughout the nation will be utilized. For the most part, these are airports equipped with

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fixed-base operators (FBOs), offering a comfortable environment with accessible parking and checkin, baggage handling, food service, office support, ground transportation, access to accommodation, and aircraft service and maintenance. Some 10 percent of Florida's airports were used for SATS demonstrations using primarily professional pilots. Avionics will be what is commercially available. SATS will have —multimodal connectivity, and it is expected that these airports will all remain in operation as SATS airports. For corporate operators, SATS will reduce travel time and eliminate the need to fly in and out of congested airports. No more airport lines and no more connecting flights! Departures and arrivals will take place within a 30-minute radius of one's home or office, premising more reasonable travel times and increased travel range.

UNIT-II

NATURAL ENVIRONMENT, REGULATORY ENVIRONMEN AND OPERATIONAL ENVIRONMENT

2.1 Introduction:

Chapter 1 examined how demand between places within a group can be addressed but left unanswered the question of what constitutes 'demand'. This is the very essence of all transportation issues. The call for a service to convey people is influenced by many factors. The principal attributes of demand need to be understood and allocated to the transport mode. In general, the 'propensity to travel' will be greater in higher-value economies, actual population clearly will have an influence and the modes of transport preferred will be influenced by availability, as well as the ability of individuals to afford certain modes. Almost all people can walk – provided the demand being analyses is not a sea journey – but beyond a certain distance they will express greater and greater desire for a more rapid mode of transport. After walking comes assisted human transport (bicycle, but could be skateboard or scooter), then public transport (bus or coach), motorbike/car, faster public transport (rail) and eventually air transport. In general, aviation is most suited to long-distance travel, but as time is as influential as distance, aircraft can be second to waterborne vehicles over Woodhead – Hirst - The air transport system Data Standards Ltd, Frame, Somerset -15/8/2008 02 The air transport system Chap 2.3d Page 25 of 45 25 short stretches of water, and so on. In this section interest is expanded, encompassing aviation but not focusing on it. The structure of landmasses and oceans that makes up the surface of the Earth, the consequent distribution of human habitation and human habits become more important. Also, and because aviation is the prime interest here, there is a brief study of the atmosphere that embraces the planet.

2.2 The Earth as a habitat

The planet Earth is a sphere roughly 13 000 km in diameter and surrounded by a relatively thin gaseous layer, the atmosphere. The latter is comprised largely of nitrogen and oxygen (four-fifths and one-fifth respectively); it is the element in which aviation plies services between communities and it forms a fragile mantle on which life depends. It has been appreciated, increasingly, that the atmosphere has a close relationship with how flora and fauna develop and thus affects, through climate and physical contexts, the habitats in which we live. This view of the Earth as a fragile and illustratively beautiful inheritance that mankind must share with all other forms of life on the planet has been heightened by images brought from space. It is a dichotomy that aerospace technology has been able to heighten awareness, but at the same time the perspectives it can offer can invite interpretations that, unhindered, will be used to engineer its demise. Many managers will appreciate this is not an unusual circumstance, as such irreconcilable balances attract attention in many endeavours. At the present time the aviation industry is very vulnerable to attacks on its conduct, which can be regarded as contrary to human good. It has a part to play in ensuring human good, which will only be achievable if the whole business is seen to have common, noble and justifiable aims.

Staying with facts about the Earth, it orbits the Sun, completing one orbit each calendar year. This cycle affects many aspects of life and people's habits, and this in turn affects the demand for travel. Because the Earth's axis of rotation is inclined (at 23.58) to the plane of the orbit, regions of the planet's surface receive solar radiation at different rates throughout the year. The year is defined into

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four phases, or seasons – spring, summer, autumn and winter – and the Earth rotates on its axis 365.25 times in a year, making 365 days (each arbitrarily subdivided into 24 hours) per calendar year, with 366 days every fourth (leap) year. The seasons are characterized by temperature variations, with 'summer' the hottest quarter of the year. The Earth's orbital inclination relative to the sun causes 'summer' to be in the middle of the calendar year in the northern hemisphere and at the changeover between calendar years in the southern hemisphere.



2.1 Position reference on the Earth's surface.

position on the Earth's surface, geographers use an angle-based grid system, as illustrated at Fig. 2.1. A meridian is a line that extends.

between the two locations around which rotation takes place, which are the planet's natural poles (the North Pole and the South Pole). Any location on the Earth's surface will lie on a meridian, which is called a longitude. The reference meridian is the Greenwich Meridian, which passes due north–south through the district of Greenwich in East London, UK. Lines of longitude are defined as degrees east and west of the Greenwich Meridian; they meet at 1808, almost in the middle of the Pacific Ocean. Along most of its length this also serves as the International Data Line.

Perpendicular to the axis of rotation and cutting through the globe halfway between the North and South Poles is the Equator. Above and below this line, any position can be defined in terms of its angular displacement, and is expressed as latitude. The Equator is therefore 08 latitude and the North and South Poles are 908 north and 908 south respectively.

In the region within 23.58 of the Earth's equator the Sun is overhead at least twice during the year, which causes the seasons to be less obvious than at locations at higher latitudes. This band is called the tropics. In the tropics the ambient temperature is usually warm, rainfall can be plentiful, but sometimes seasonal (except in the centre of continental-sized landmasses), and snow is almost

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unknown (except at very high altitudes). Populations are plentiful and have typically sufficient food and resources to live equitably.

Thus, historically there has been some, but little, temptation to travel to find food, and so on, so different tropical regions tend to be culturally distinct and diverse, in terms of language, customs and in many cases religion.

At moderate, or so-called temperate, latitudes there is a distinct seasonal change throughout the year and associated climatic activity; with that have come different habits and different kinds of human populations. Largely these arise from temperature and rainfall changes and the way they affect humans in terms of their use of the land. Crops and people react in an annual pattern, induced by the warmer conditions of summer and the colder conditions of winter. There has been a greater temptation to migrate or to travel to conduct trade in these regions. Human movement patterns have caused the distinctions between cultures to reduce, although integration of this nature has not always been achieved peacefully. The desire to trade has caused some populations in these regions to develop resource surpluses, either through exploitation of natural elements – foods and materials – or by manufacturing. The demand for travel has therefore been greater in temperate regions than anywhere else on Earth, and economic prosperity, thus far in history at least, has evolved at a greater pace in temperate regions of the world.

Finally, at the most extreme latitudes are the polar regions. At these latitudes the Sun can be visible for a large proportion of the 24-hour day in the 'summer' and similarly the 'winter' can be largely dark. Snow and ice abounds, as temperatures are moderate to low. People are not numerous and their lives are hardy and relatively inclusive, with some limited trade between them and their neighbors.

The development of population and its ethnic habits, interesting as it is, has been alluded to in very general terms above, and it will not be delved into any more deeply. What is significant to the air transport researcher is that successive transportation developments, from travelling on the back of animals (horses and camels especially), through animal-drawn wagons and into the era of mechanically assisted travel, have cast aside some of the barriers between populations. The aeroplane has played a large part in the last 100 years or so, its speed and ease of use leading to accelerated rates of change in demand and a consequent expansion of travel habits between populations.

Even before air travel was available, the ease of travel throughout various world zones contributed to accelerated economic success in many populations. With economic prosperity came sanitation and medical care improvements that led to longer lives, and throughout the world there has been a massive human population explosion. From an aviation perspective, these circumstances initially saw growth in business demand, but now leisure travel has outgrown business demand. There is also a coincident rise in trade, and while much of the bulk cargo is best conveyed by surface means,Woodhead – Hirst - The air transport system Data Standards Ltd, Frome, Somerset – 15/8/2008 02 The air transport system Chap 2.3d Page 28 of 45 the speed of air travel has led to a boom in demand for the conveyance of perishable commodities and small high-value packages.

The telecommunication advances pioneered in the 20th century cannot be overlooked. They affect a population by introducing more news of places and events that stir the interest of people whose lives would not have been able to gather such information so readily in the past. There has been a longheld prognosis that with instant access to real-time news, telephone and video links, etc., populations would not need to travel to do business – they could do it 'on-line'. The converse effect seems to be true, with the greater appreciation of what is available elsewhere leading to populations wanting to see the world for themselves. It is having profound effects on the way that cultures evolve. There is little doubt that global air travel demand will continue to grow; the only uncertainty is

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whether progress will be smooth or hesitant, slow or fast, and to what extent the changes will be accommodated peacefully or with friction. It is estimated that while the world population grew from some 2.5 billion in 1950 to 6 billion in 2000, it will expand further, to around 9.25 billion, by 2050. It seems inevitable that the demand for air travel will soar rather than recede, which given its astonishing growth throughout the last half of the 20th century will pose some interesting problems.

2.3 The Earth: physical issues affecting demand

2.3.1 Surface

The planet's surface is the crust, and it is that part of the Earth on which all human activity takes place. The surface is divided into regions (tectonic plates) that move, infinitesimally slowly, across the Earth's surface, carried by the flow patterns in the magma beneath the crust. Where plates meet, the surface is ruptured and pushed upwards, creating mountains, and where they subdivide, which is usually in oceans, there are rifts, upon which volcanoes will form. There can also be volcanoes over regions where two plates meet, especially if one subducts beneath the other. These geological features define the shapes of continents and affect the fertility of land, and often accessibility, and thus govern how population is distributed over the Earth's landmasses. Intrinsically all the land that is populated is in the form of islands, either large or small.

Between the landmasses there is water. The level of the water varies diurnally, owing to gravitational effects creating tides, and can be referred to as the mean sea level (MSL). The accurate measurement of terrain height has resulted in maps that express height above mean sea level (AMSL) worldwide. Knowledge of the relative height of terrain is especially important in aviation, either with regard to being significant to operations

Wood head – Hirst - The air transport system Data Standards Ltd, Frome, Somerset – 15/8/2008 02 The air transport system Chap 2.3d Page 29 of 45 around airports or because in some parts of the world the landmass rises high enough to represent a significant en route hazard to aviation operations.

2.3.2 Core

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The Earth comprises layers of material, the properties of which are manifold but which have only an occasional impact on aviation. Examples are volcanic ash, which can be a hazard to aviation because of its abrasive and suffocating nature, and earthquakes, which are hardly welcome anywhere. However, one particular property has been exploited by navigators for many centuries. The central part of the Earth comprises molten rock that has a high proportion of iron in its content, which is responsible for a strong magnetic field. The field emerged through 'magnetic poles' that are roughly coincident with the natural poles, and thus a magnetically sensitive needle will align itself to the direction of the magnetic poles. Across most of the Earth's surface it will be at a small angular displacement from the 'true' pole; this is a predictable error, called magnetic compass to guide the direction of travel between times when they could observe the sun or stars. Aircraft navigation initially inherited this discipline and the legacy where the magnetic compass, simple as it is, is still installed on all aircraft – large or small.

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responsible for a strong magnetic field. The field emerged through 'magnetic poles' that are roughly coincident with the natural poles, and thus a magnetically sensitive needle will align itself to the direction of the magnetic poles. Across most of the Earth's surface it will be at a small angular displacement from the 'true' pole; this is a predictable error, called magnetic variation. This kind of field detector is the magnetic compass. Nautical navigators used the magnetic compass to guide the direction of travel between times when they could observe the sun or stars. Aircraft navigation initially inherited this discipline and the legacy where the magnetic compass, simple as it is, is still installed on all aircraft – large or small.

2.3.3 Continents

These are the largest landmasses and have been the cradles for distinct cultural divisions in humanity. Over preceding centuries travel between these regions has risen from a trickle, through recorded periods of exploration, to the time when sea-going vessels have been able to convey significant numbers of people, initially one way, thus adding momentum to migratory patterns, and merchant ships have been able to carry goods for international trade. When the aeroplane appeared, it brought the time taken to travel anywhere in the world down to an insignificant proportion of alifetime, and led to an explosion in the demand for travel. If a 24-hour time horizon is indicative of what marks the limit for mass migration, the aero plane has opened the world to all people.

People have always wanted to travel, to engage in trade, for territorial wants or through sheer curiosity. In some continents mountainous landmass regions have deterred surface travel. Likewise, certain regions of the seas can be so tempestuous that even short sea journeys can be hazardous. These are examples of physical characteristics that have contributed to the distribution of population and to the shape of the demand for travel between them.

While aviation has offered wider access between communities over the last century, the majority of the world's population has still not yet flown. Only a small fraction of the population flies habitually and regularly. Nevertheless, the demand for air travel has grown rapidly, the first significant levels of commercial operations commencing only in the 1930s. All the indices that can be used to predict demand suggest that there will continue to be growth in air transport demand for many decades into the future, and the rate at which it will rise will equal or exceed growth rates already recorded. The industry needs to have a good idea of what is likely to be in store, so developing ways to forecast demand is essential.

2.4 The shape of demand

Knowing what 'demand' (passengers per unit of time) there is for a service at the present time is essential to planning the introduction of a transportation service. The desire is to provide a service that will continue to serve demand. Thus, some idea is desirable as to how service demand will evolve over time. This is traffic forecasting.

Traffic forecasters tend to divide the world's population into entities and to assess what propensity there is to travel between various clusters of people. One way to do this is to subdivide them as national populations, within some 200 countries. However, countries are territories on the Earth's surface (defined by physical features or specific references, mainly on the landmasses) governed by their own rules, so sometimes this is too coarse a way to examine the diversity of the population. Most large nations have their own language and some nations share a common language, but in some cases, such as when a 'nation' comprises a scattering of islands, there can be many languages in one realm. Then, within a country, the population is not evenly distributed. It can be sparsely spread throughout rural areas or congregated in cities. In most nations there is one city that is

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the administrative, legislative and governmental hub (although these functions are divided in some countries), which is referred to as the capital city. It is usual for the capital city to have the busiest airport (or set of airports) in the nation. Other cities or regions may have their own airports.

Throughout the world there are some 2000 airports with daily scheduled services that radiate from them – and the number grows annually. Great areas, such as China, are just beginning to expand their economic capability and are investing in airports at a rate that equals the rate at which they opened in North America in its most expansive period. Worldwide there are also small airports that are beginning to attract people to use them, to sample convenience of access or to sample a new genre of air travel experience, and thus, by 2050, the actual number of airports that will host scheduled services might be considerably more. Already some 30000 airfields and strips exist worldwide, albeit the majority of these are used by general and business aviation, whose activities are distinct from those of airlines.

Airlines only operate between locations where there is sufficient demand for their services to be warranted – be that for passengers or freight. Therefore, if there is a steady demand, they will offer a scheduled service, perhaps daily or even several times daily, if demand is very high. Ad hoc demand can be catered for through charters, where the aircraft will arrive to operate a service when there is adequate demand only. Where there is a specific demand, such as for holiday travel, the service might be provided seasonally, and the operator of a regular timetable who sells seats through holiday companies will be a scheduled carrier but may be a so-called inclusive-tour (I/T) operator.

2.5 Demand forecasting

Airlines assess the possibility of a new route and airports look into the possibilities of what they should promote as new routes by conducting traffic forecaststudies.Traffic forecasting attempts to predict the demand on routes, usually by looking at current situations that affect demand and by considering their probable evolution over the period of time of interest to them. The methodologies in use vary depending on the circumstances and the data available. Traffic forecasting is fundamental to establishing the scale and scope of all operations considered in later chapters. Nowadays, forecasting can be conducted globally (looking at the demand between nations) or specifically (looking at the demand between points). Both kinds of forecasting will be implied in the review of forecasting methods that follows.

2.5.1 Historical demand forecasting

If there are historical data from previous years these may be a practical measurement that can be adapted to forecast a predicted demand. This is the least risky way of predicting demand, but it is not so straightforward as might be imagined.

Plotting such data as points, with demand (passengers per unit of time) on the vertical axis and years across the horizontal axis, will invariably reveal that the data points are 'scattered'. Real-life data are influenced by so many events and factors that it would be unreasonable ever to expect the data to sit on an obvious line. While it is easy to draw a straight line by eye, different people will draw different lines

The mathematical solution is to use a process of 'best fit'. This is readily done using modern spreadsheet programs, which will also furnish a measure of the correlation coefficient or one of many other 'goodness of fit' expressions. This is the simplest possible forecast, but there are many good reasons for believing that it is the wrong geometric fit to assume

For example, a steady percentage annual growth rate, which might be a realistic expectation, will translate into a curve that becomes increasingly steep over time. There may be market conditions that will mitigate against continuous growth – all travel markets tend to 'saturate' at some time – so this is an assumption that cannot always be depended upon (see Fig. 2.2).

The discussion shows that the extrapolation of a traffic sample is a risky choice for the mathematical observer of data. It is inevitable that the further into the future the observer probes, the less certainty there will be in the quality of the results obtained. Clearly, having historical data is better than having nothing, but it is hardly ever a totally reliably guide to what will happen on individual airline routes.



Historical extrapolation forecast

2.2 Example of a historical traffic extrapolation.

2.5.2 Comparative analysis

If a situation with no historical data is being studied, information regarding similar circumstances – between airports at similar distances and with similar local population interests, for example – can be adapted. Imagine that the demands on services from a well-established airport to three particular destinations are known. The simplest deduction to make is that the ratio of demand to all three airports from another airport in the same country might be expected to relate to these services. That relationship could be in terms of the same ranking, and perhaps in similar proportions. Whether it would be a small or significant proportion of the existing demand is only determined by having knowledge of several additional issues. These are 'community of interest factors' and can include such aspects as:

- the ground-based infrastructure that serves each of the airports
- local geographic features

• the distribution of the population, in social and cultural categories, throughout the region around the airports.

Airport catchment areas are the regions from where demand is drawn. They can be illustrated as isochrome charts (see Fig. 2.3), diagrams where lines of equivalent time to access are drawn. Inevitably, the catchment areas of neighboring airports can overlap, meaning that the airports will compete: strongly in regions where the access criteria are similar, but less so as one gets closer to one or other of the airports. A very decisive factor is the



2.3 An airport isochrome diagram (Source: Birmingham Airport).

Existing volume of services. A large international airport will dominate over a small regional service airport when all other factors in the catchment assessment equations are equal, for example.

Statistical methods can be used to factor the propensity to use a particular airport, but in every case there are difficulties because the number of influences is very high. Therefore, relating them by using factors in equations is often difficult to justify.

Comparative data are therefore a valuable source of comfort for a forecaster. The data can help to predict, if not exactly what will happen, what possibilities are likely to be evident in the future. The astute user is asked to take note of trends and to be prepared to expect comparative databased forecasts to offer credible, but not always predictable, scenarios.

2.5.3 Theoretical demand models

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When there is no clear precedent on which to base traffic estimates, in effect the forecaster has a clean sheet of paper and the only option left is to use a theoretical process. The many techniques that can be used often will adapt from historical or comparative studies, perhaps in related traffic fields; any form of surface travel that links the same regions can be a first-order indicator of the circumstances that pertain and will influence the characteristics of a theoretical forecast. These notes will concentrate on one technique, which is the most widely used but not the universal choice of forecasters. This is the so-called 'gravity model'.

The idea of treating populations as units with attractiveness for one another, akin to gravitational pull, was first proposed as long ago as the mid-19th century. A gravity model equation predicts the scale of demand between two locations by assuming there is attractiveness which is proportional to:

- the population at each location, such that as population increases so does demand
- the distance between them, such that as distance increases demand decreases.

The formula can be factored in many ways. In the simplest case, where population is assumed to be a linear relationship and range is an inverse square (as in gravity equations in physics), the demand between two towns with populations P1 and P2 and distance r apart would be given by

Passenger demand= k p1p2

r2

Where

P1 and P2 are the populations at locations 1 and 2 respectively

r is the distance between them

k is a factor that reconciles units

This yields a result that shows that two similar-sized towns generate greater demand if they are closer together. This is true for all transport modes, so a gravity model result has to be factored to extract the air transport proportion. The travel demand between two adjacent housing estates will perhaps be considerable, but the proportion of people that would use an aircraft to make the journey can be regarded as nil. Two similar patches of population a few miles apart in almost any country will still generate very little, and justifiably assumed to be nil, air transport demand. If the short distance is flat agricultural land, the answer is almost certain to be nil, but if the area is a treacherous patch of water, the aeroplane could be the most convenient, even safest, mode of all possible transport options. The judgement that must be applied to make a justifiable modal-split across all possible transport modes should not be guesswork, and this is where comparative or historical data are often used to 'calibrate' the assumptions that are incorporated.

Experience has shown that an analogous gravity model equation, with an r2 term, for example, does not correlate with real-life data. The exponent value (2 in the analogous version) tends to be a lower value when assessing demand between destinations that have other transport mode competitors, but can approach 2, or be even higher, between destinations with little transport mode competition. Islands have different demand characteristics that can affect the best value to use.

Even more significantly, population attributes such as density, social and cultural categories have to be taken into account. This is usually accommodated by multiplying the basic demand equation by factors.

Finally, as busy airports tend to be more successful at attracting passengers than less busy airports, gravity model applications are often more reliable if they use existing traffic levels, not population. Thus, the simple equation becomes

Passenger demand =f(K1,K2,...,KX)(T1,T2)

r2

where

K1 to Kx are factors that represent relevant population attributes

T1, T2 are the traffic levels at the two airports of interest

n is an exponent that usually relates to geographical circumstances

r is the distance between them

Long-range Demand



If traffic level is used, then a gravity model-based assessment of demand is almost impossible for a new airport. A mixture of historical data, reading across from equivalent situations, plus gravity modelling (see Fig. 2.4) is the best approach.

The assumptions that relate to population attributes are, in many respects, also related to fare structure. Increasingly, therefore, as more complex fare structures have emerged, gravity forecasts have also had to be subdivided into categories that reflect the journey purpose and to assume their bias towards specific fare structures. For example, the behaviour of business and leisure travellers affects demand considerably, and a modelling technique that considers seasonal variations is also used when detailed forecasting is conducted.

At this stage the basis on which forecasts are developed has been described. The significance of the details referred to above and the uncertainties that surround long-term forecasts re-emerge as the objectives steering strategic decision-making in businesses and are considered later.

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It is important to appreciate that all forecasts are based on data drawn and decisions taken at a particular point in time and therefore they become stale and need to be revisited at frequent intervals. Adjustments can address changes that have occurred in demography, local developments (for example new surface infrastructure) or in society overall. If town populations are expanding or diminishing, the rate of change needs to be determined and any shift in the distribution of wealth needs to be assessed and quantified.

2.6 The reliability of forecasts

Forecasting is a modelling process that attempts to describe the habits of people and requires judgement concerning the relationship between variables that might seem to have little statistical correlation. A good forecaster is one who has a reputation for making good predictions, and the common wisdom is that consistently good results indicate there is a sharp mind behind the analytical processes on which the forecasts are built. This is true, without doubt, but the goodness comes as much from intuition as it does from analytical processes.

Forecasting will not get easier as more historical or comparative data are accumulated. Aviation has greatly affected the way that communities have responded to travel opportunities, largely through providing access to more distant locations with greater ease and at reasonable cost. Business-related connections have grown rapidly, with aviation offering almost instant faceto-face access to any community worldwide, but will the development of more accessible real-time telecommunication links begin to impact the rate of growth? The patterns of migration of the old, driven by disease or war, have been swamped by the opportunities that have opened up in the last few decades, with access to places attributed with better standards of living. The opportunity for people to keep in touch, and even to move back to their original domicile if they so wish, is greater than ever. The first generation of leisure destinations – almost exclusively within nations – was established barely 200 years ago, but these locations have seen their exclusivity diminished as new leisure destinations, tailored to meet demand that was hitherto unimaginable, have emerged well beyond national borders.

In turn, these socioeconomic developments have opened new legislative issues, in terms of who profits from the services that link communities, who has access to what nations, where and when, and so on. Furthermore, political influences cannot be ignored and are not as constant as might be imagined. The legislative processes that need to be understood in order to integrate consideration of these issues are addressed in the next chapter.

2.7 The breadth of regulation

There are two major aspects to regulation – economic and technical. They are administered separately in most countries and there is a major international coordination body in each sphere, these being the International Civil Aviation Organization (ICAO) looking after safetyorientated regulation and the International Air Transport Association (IATA) looking after commercially sensitive regulation.

The structure and function of each will be examined separately, but as their separate responsibilities are shared over a broad common boundary, the degree to which individual nations are free to negotiate their own terms of reference for legislation, especially nation-to-nation, need to be considered. Most combinations of nations have negotiated and ratified 'bilateral traffic agreements. These are reviewed periodically, and overall the rules that emerge from such negotiations will set limits on points of access, capacity on services and the actual designation of air service suppliers. The negotiations have to respect the influence of 'freedoms of the air', which are vested in ICAO and detailed later, and the competitiveness of nations in seeking to manage market share, through the use of computerized reservation systems (CRS) and such mechanisms as code-sharing, which are topics

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vested within IATA. Both organizations will monitor such developments and, in many cases,, through their regular involvement and oversight, they can assist in the drafting of such agreements, thus saving time and money.

Where 'deregulation' is being approved, national authorities are given freedom to dismantle components of their own regulatory organization and procedures, where they so wish. However, an overriding provision is that the less bureaucratic legislative processes that emerge must still be compatible with the requirements of the international community. The clearest example of this has been the dismantling of route-licensing procedures, whereby an airline had to seek approval to compete on a route with an incumbent operator. While allowed in principle, this is not allowed to proceed without some restraint, for example in terms of respecting capacity constraints at airports, which might be administered by the IATA through its Scheduling Services division.

Similar issues are arising more frequently nowadays as 'privatization' ofpublicly owned entities – the airport and airspace service provision in many countries – gathers pace. ICAO and IATA are still the organizations to which the national authorities have to defer many obligations that will impinge on international operations. It is no good, to consider an extreme case, if a nation uses a unique navigation system, as this will impose an operating cost disadvantage on airlines that use that nation's airspace over those of its competitors who do not visit that nation.

Deregulation and privatization are topics that will arise as the themes in later chapters are examined in greater detail. Their introduction here is to provide a reminder that these are not the almost maverick actions that popular press coverage will sometimes describe.

2.7.1 International Civil Aviation Organization (ICAO)

The International Civil Aviation Organization (ICAO) is the supreme legislative body overseeing technical-based aspects of international air transport operations. ICAO takes responsibility for the framework against which much of the international air law pertaining to operations and safety worldwide is drafted.

Its responsibilities date from 1944, when it was founded, but many of the principles it adheres to can be found in legislation that pre-dates this period. It was in Europe, where nations were cheek by jowl and air travel was beginning to take hold, that the first international air agreements were drafted and enacted, from as early as 1919. Once in place, regulations have to live and breathe. They are under perpetual review, with experts tracking every issue, almost day-by-day, and urging the re-drafting of time-expired or hole-riddled statutes. As international laws are debated at length before being enacted, they can seem to be part of a process that, to those driven by entrepreneurial flair, is apparently staid, slow and counter-productive. Thus far, ICAO has walked the tightrope between being overzealous and too relaxed very successfully. Given the tribulations on which it has often to be arbitrator, this is a statement made with considerable respect.

ICAO is headquartered in Montreal, Canada, and has regional offices worldwide. All United Nation (UN) States are eligible members, and at the current time that makes over 200. Representatives from all contracting nations (there are few exceptions from the UN membership) form the ICAO Assembly, which meets three-yearly, reviews working and sets future policy. At the same meeting a three-yearly budget is also set.

The Assembly is assisted in its more regular duties by a Council, which comprises members from 36 States. The composition of the Council is readdressed at each three-yearly Assembly meeting. As a part of its routine procedures the Council ratifies ICAO Standards and Recommended Practices

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(SARPs), which are the basis of its most important legislative output, the ICAO Annexes. These are so named because the first SARPs were written and published as Annexes to the ICAO inaugural Chicago Convention. These fundamental statutes remain in that format, expanded from the 15 produced after 1944 to 18 in current usage. The complete list is given in Table 3.1. The procedures engendered by these Annexes assure commonality, in terms of equipment and procedures, accepted levels of safety, and so on.

Annex	Subject
1	Personnel licensing
2	Rules of the air
3	Meteorological services for international air navigation
4	Aeronautical charts
5	Units of measurement to be used in air and on ground operations
6	Operation of aircraft
7	Aircraft nationality and registration marks
8	Airworthiness of aircraft
9	Facilitation
10	Aeronautical telecommunications
11	Air traffic services
12	Search and rescue
13	Aircraft accident and incident investigation
14	Aerodromes
15	Aeronautical information services
16	Environmental protection
17	Security
18	The safe transport of dangerous goods by air

Table 3.1 Annexes of the ICAO Chicago Convention

Specific duties with regard to ensuring the SARPs are up-to-date and technically proactive are vested in several ICAO Bureau. These include the Air Navigation Bureau, which develops technical studies relating to the safety, regularity and efficiency of international air navigation. It has had a very significant role to play over the last two decades or so, in ensuring that debate worldwide has led to acceptable international air navigation standards that will allow an expansion in the capability of airspace service provision. Without this development the benefits of new systems that will ensure efficient use of air vehicles and airspace would have been almost certainly lost. The committee that has handled this work is the Future Air Navigation Systems (FANS) Committee, and its responsibilities and achievements in terms of defining the attribute of global communication navigation and surveillance and air traffic management (CNS/ATM) processes will become increasingly apparent in later chapters.

The Air Transport Bureau within ICAO is the division within which there is perhaps the greatest overlap with IATA. They consider unlawful interference (terrorism and security threats) in particular, and especially they have influenced the extension of the Annexes over the years. Alongside the major technical bureau is the Legal Committee and such specialist units as those that administer the Technical Co-operation programme. Without a source of support from what is the center of activity in respect of future developments, the majority of nations – whose interest in new systems is not associated with their technical development – would be left with the impression that the

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organizationwas intent only on giving support and encouragement to the richer nations. Finally, ICAO is the source of a vital set of agreements that are principally commercial. These are the 'freedoms of the air', which were first expressed in the 1944 Chicago Convention. They have been extended since and are so fundamental to the way that bilateral agreements, and more resenting 'de-regulation' developments, are scoped that they are presented in more detail later in this chapter.

2.7.2 International Air Transport Association (IATA)

The International Air Transport Association (IATA) was created almost at the same time as ICAO, and also with worldwide reach and also headquartered in Montreal. However, this is not an organization that sets rules for governments. It is a less kindred association of representatives from privately and publicly owned aircraft operators. Those organizations that are members have chosen to join it, and the 230 airline members as of 2008 (of some thousand airlines worldwide) were responsible for 95% of the total passenger-kilometers performed each year.

IATA produce considerable quantities of statistical data concentrated on routes and financial and other business information. These data tend to be derived from member company records, as the membership is almost wholly scheduled carriers. They are a useful source for forecasters, but IATA does withhold commercially sensitive information from the public.

IATA can pick up current technical affairs, but these tend to be ICAO's responsibility, and they only take issue where there are commercial implications. An example in the 1980s was the way that IATA addressed issues with the bias of computerized reservation systems (CRS) and acted as an authority able to draft and impose a workable set of fair-trading rules. At the present time IATA is active with regard to several issues in the areas of safety, security, the environment and e-ticketing.

IATA has standing and special committees that address airlines, airports, cargo and other civil aviation and travel issues. For example, while ICAO has played a leading role in setting CNS/ATM standards through the workings of its Future Air Navigation Systems (FANS) committee, IATA addresses issues concerned with the financing and investment requirements that arise when implementing such systems.

As well as looking ahead, IATA has many functions that are a legacy and still represent a foundation upon which many financial operational aspects stand. IATA tariffs were ticket prices set in the days when economic regulation was stronger than it is today. At one time all airlines issued 'IATA tickets', which were multi-layered coupons that made every airline ticket look alike. If a traveler conducted more than one flight, with different operators, IATA would process the coupons, applying pro rata rules for the distribution of revenue, through the organization's ticket clearance system. This system still exists and handles almost all such work to this day. It is a vital part of the revenue management service department within every international airline, even if they are not IATA members.

Additionally, the IATA Scheduling Services are responsible for the development and maintenance of standards and procedures for the exchange of schedule data between airlines and airports and airport coordinators, at the six-monthly spaced IATA Schedules Conferences. The purpose of this voluntary assembly of both IATA and non-IATA airlines worldwide is to provide a forum for the allocation of slots at 'fully coordinated' airports and for reaching consensus on the schedule adjustments necessary to conform to airport capacity limitations.

On behalf of the Conference, IATA manages and publishes the Worldwide Scheduling Guidelines (WSG). These guidelines are developed in consultation with the airline and airport coordinator communities. IATA sums up its work with the words that its 'intent is to provide guidance on

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managing the allocation of scarce resources at airports on a fair, transparent and non-discriminatory basis'.

Throughout the immediate post-war decades almost all of the world's major airlines were members of IATA, and it was through this organization that many commercial rules were created and implemented. The most unpopular was that IATA had a preferred fares structure that (according to those airlines that eschewed IATA membership) kept fares high. The degree to which IATA set fares is nowadays viewed less harshly, for while they certainly did contribute to competition being limited, they introduced sustainable revenue levels and provided additional services that set benchmarks that were often unrecognized, in terms of their importance, at the time.

One aspect where IATA has total control is the allocation of airline and airport codes. This is a small but vital harmonization task, and at one time all airlines had a two-letter code that was a part of their flight numbering. Thus, KL123 was a flight by KLM (from the Netherlands), AF was a flight by Air France, and so on. Nowadays airlines are more numerous than the limited combination (650 or so) that can be arranged with two letters, so aletter and a number are sometimes used and three-letter codes have also been introduced. Similarly, IATA administers the allocation of three-letter codes to airports, so LHR is London Heathrow while LGW is London Gatwick. Some are less easy to recognize, like YYZ for Toronto, Canada. By having these codes administered from a single repository, the many machines that handle airline flight data, baggage carrying airline and airport codes on bar-code tags, and so on, have a solid assurance of the presence of unique codes.

Charter operators work collaboratively with IATA on such issues as airport scheduling, but are not usually IATA members. Indeed, low-cost carrier (LCC) airlines are more often than not vociferously opposed to IATA, because they disagree with the discipline applied to fares policies in the past. Long-standing airlines, respectful of how IATA's mechanisms made slender operational situations more robust, are barely able to express their anger at the antics of these more contemptuous newcomers. IATA sits on the fence on such matters, and will engender debate and facilitate developments that it believes will be in the best long-term interests of the business. If that means the organization will have a diminished role, it will be because that is the way that the businesses have decided that things will be. At the present time, however, there is no sign that any pessimism should prevail in the corridors of IATA.

2.8 National authorities

Within each country, the national authority is the main point of contact with a regulatory body. Almost every country in the world has a Department of Civil Aviation (sometimes called DCA). It can be referred to as the DCA, with the head called the Director-General of Civil Aviation (DGCA). It is a part of the national 'civil service' and the staff will be partly specialists and partly governmental administrators who move between departments. In many large countries, the task is large enough to have a specialist body, within which staff are able to follow a refined career structure and where incoming and departing administrative staff are comparatively low in number. In the USA the specialist team is the Federal Aviation Administration (FAA) and in Britain the Civil Aviation Authority (CAA). It is a member of the national authority that will be a nation's representative in ICAO, and the organization will have less clear but equally strong links with IATA.

Essential in all organizations, invariably, are two different groups. In the UK these are termed the Economic Regulation Group (ERG) and Safety Regulation Group (SRG). There are additional groups in all regulatory authorities for administration and personnel, for example.

Economic regulators have a role with regard to local operations, but thishas diminished in recent years in the USA and Europe, and this inward-looking role is diminishing elsewhere. Meanwhile, internationally the regulators are still responsible for guiding officials, from the government and airlines, on the content of bilateral agreements. An aviation authority can advise in situations where airlines are vying for traffic rights between countries, the right to impose conditions on aircraft entering the country from another country, slots at airports, and so on. In any solutions they have to accord to the 'freedoms of the air'.

The organization is easily portrayed in an unfavorable light when it applies rules that try to represent a compromise that arises from political wrangling between States. There are instances, however, when the authority is acting upon international or moral mandates. The fact is that competitive businesses believe strongly in freedom of choice and action, and do not like constraints. Regulators therefore are often an easy target for grumbles and complaints. Because this is a serious, potentially destabilizing, influence on the air transport industry, in most countries there are organizations that are granted the right to curtail overzealous regulation. In Britain the 'watchdog' with most appropriate access is the Air Transport Users Committee (ATUC), which is a forum of politicians, representatives of industry (airlines and airports) and academics.

Safety regulators are much more involved with day-to-day operations than their economic counterparts. They will apply directly, or with appropriate modification, the requirements of the ICAO Annexes. Safety regulators are empowered to demand access to facilities and records, and periodically they will check all safety documentation within airlines and at airports. They have a duty to audit and to feedback information, and whereas it was often the case that they would assist in developing solutions, newer powers mean that they are much less involved in solving problems. They can point towards examples of best practice and encourage the dissemination of information that they believe is conducive to safety, but nowadays they operate largely in a quality assurance role and not as consultants.

This is a part of the way that government-allied organizations have been reorganized to streamline their functions, to work with fewer staff and thus to impose a smaller overhead on what are increasingly real businesses, which were becoming critical of the way that regulatory functions were operated, given that they felt that their fees were unjustifiable. It is a difficult judgement to make, and to ensure that power is shared equitably there are organizations that will act as a 'safety valve' in that they will collect and process complaints and are tasked to do so in a critical but progressive climate.

The influences of the economic and safety regulation services arise at many points in this book and will be described in greater detail at theappropriate times. Meanwhile, it should be appreciated that the picture presented so far is incomplete without mention of the fact that most nations with sizeable aviation operations also have organizations dedicated to specific safety functions. For example, in large countries it is traditional to have a team of scientists and engineers, employed as civil servants and quite apart from the regulatory authority, whose job is to investigate aircraft accidents. They are thus empowered to question the integrity and capabilities of all organizations associated with aircraft accidents – even the regulators. In Britain it is the Aircraft Accident Investigation Branch (AAIB), and in the USA the National Transportation Safety Board (NTSB) has oversight of all transportation modes, including aviation. They disseminate preliminary, occasionally intermediate, and final reports on all significant incidents, so that the public domain is aware of safety issues.

2.9 Service properties

It is important to keep track of the scale and characteristics of the air transport business. Each national authority collects and collates data on operations to/from airports, conducted by the airlines and other

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aircraft operators in their region of jurisdiction, and supplies information to the statistical bureau of ICAO.

The ICAO historically has been the best source internationally of all statistical data that define the properties of the services that are operated worldwide. The next examples are drawn from the annual statistical review that ICAO used to produce around August/September each year. However, from 2007 this procedure has been discontinued.

2.9.1 Service volumes

Figure 3.1 shows that passengers carried annually in all civil operations rose some 50% in the 10 years up to 2005, and in the last year for which data are shown, over 2 billion passengers were carried for the first time. The continuing popularity of air travel is the source of one of its most serious problems – capacity. Even today the vast majority of the world's population never uses an airliner, but as affluence extends then access to this mode of transport will be exploited. The potential for air travel is far from reaching a climax. It may be near its peak in some countries, such as the UK and USA, where the number of journeys per head of population is showing signs of reaching a plateau. However, in countries like China the explosive demand of recent years is expected to continue unabated as the nation's fortunes increase. Several other nations are in the same category. ICAO statistics show, for example, that China climbed from fifth place in 1979 to second in 2005.



The regulatory environment 55

It has been commented that much safety regulation work, within ICAO and through the national authorities, concentrates on establishing and maintaining high standards. The plot in Fig, updated annually by ICAO, has been the aviation safety benchmark quoted by aviation commentators and safety specialists for many decades.

The graph shows that, according to the fatality rate, safety levels do improve gradually. There are some setback years, but overall the trend has been maintaining a healthy, downwards, trend for some 50 years. Safety regulators recognize that they have to be proactive in encouraging legislative procedures that will arise from knowledge of issues and remedies.

One indication of the pivotal role of safety regulation is that ICAO Annexes require that key staff, and specifically aircrew, aircraft maintenance


Engineers, air traffic controllers and dispatchers, are all trained to statutory levels of competence – tested by examination and periodically checked – throughout the world. These are the people that are effectively mandated as the real custodians of the world air transport safety record. Operations will be viewed and regulations modified as evidence emerges of where rule changes can be justified. Meanwhile the training, certification and monitoring of personnel licensing standards is a national responsibility and is laid down in national policy.

Finally, consider fuel costs. This is a contemporary topic, but even so it has the potential to be the most important influence on economic performance, and even on demand, and thus overall system operations. Figure 3.3 shows the way that fuel costs have changed, as a proportion of airline costs overall, over the last 10 years. This is indicative of the depth to which statistical data are collected and how valuable it can be to policymakers in the industry.

It is possible to find more detailed statistics for individual operations in national accounts (the FAA in the USA and the CAA in the UK have extensive statistical summaries on their own websites, which detail current situations and historical trends).

Clearly ICAO is a vital source of statistical information, but there are equally valuable data sources, including the IATA and national authorities. The annual accounts of airlines and other aviation businesses are often of interest, but are less clearly reliable long-term sources of information, because they are a source designed to express the attributes of the business and to extol, rather than be critical – when necessary – of the business performance. This reflects an issue that arises as a more detailed view of the



Complete system emerges, because a stakeholder bias in a report will necessarily focus on the properties that are of interest to that subset of individuals. It is the international and national authorities that tend to gather collate and disseminate the most useful of all reports that detail system properties.

2.9.2 International air service agreements

An issue that drew delegates to the 1944 Chicago Convention was that a concept in all aviation legislation was acceptance that nations hold 'sovereignty' over the airspace above their territory and over water adjacent to that land. The limits of airspace sovereignty extend much further than territorial waters on the sea, because they are arranged to meet where countries border a relatively small body of water. Over oceans there is no sovereignty as such, but one or more bordering nations will accept responsibility for acting as an airspace control authority, thus ensuring that internationally agreed safety mandates are met in these areas.

A consequence of 'sovereignty' is that people need permission to fly into and out of, or over, a nation's airspace. Overlying rights are sometimes taken for granted, but these can need careful preplanning in some parts of the world. The right to fly an aeroplane over someone's territory if there are significant political differences can be a major instrument for a government to use in order to express its displeasure with a nation.

These issues led to the formulation of bilateral agreements, as already explained. In order to ensure accordance with international mandates these agreements incorporated the definitions of the 'freedoms of the air' that were drafted in 1944. At the Chicago Convention five ways of expressing how a country could have its rights to overfly or land within another nation – for passenger or technical purposes – were defined. These were called the 'five freedoms of the air' and are expressed diagrammatically in Fig.

These definitions were adequate in the early days of long-haul operations, because such flights often stopped to refuel in countries between the origin and destination, and the freedoms allowed such 'technical stops' to be conducted in the name of safety but without the supplier nation losing traffic to a dominant carrier. With the emergence of intra-states, like the European Union (EU), where individual member states have their own airspace but now trade freely across national boundaries, 'deregulation' has taken hold, and this, and similar loosening of trade restraints elsewhere since the

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1980s, has led to three additional freedoms being defined. These are shown in Fig. 3.5. They are sometimes referred to as 'freedoms of cabotage'. In the ultimate freedoms (the seventh and eighth), the country has virtually ceded the right to let anyone fly services within or to/from their nation.

Europe is the most obvious example of where such liberal traffic rights are

ceded, because an EU transport policy, implemented in stages throughout the 1990s, has been to annul all diplomatic constraints. For example, any EU registered airline can officially operate between any two EU nations. Some non-EU countries have joined in the spirit of deregulation and allow themselves, for air transport service purposes, to be treated as an EU nation, such as Switzerland and, to a lesser extent, Norway



When an airline from outside the EU wants to fly into the EU and to carry traffic internally, there is more to consider. For example, an African airline might fly into Europe and stops at two locations, say flying to London via Amsterdam, and have an agreement to pick up passengers in Amsterdam and carry them to London. They might not be allowed to advertise this service under their own name, but if they coordinated the service with an existing carrier on that route the European carrier could advertise it for them. The service would be offered with the EU airline's code and would be an

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example of a wider practice, called 'code-sharing'. The basic right to operate such a service must be bound to a bilateral agreement.



Bilateral agreements have already been explained and ensure that where there is an opportunity for the sharing of demand between two nations, the airlines have the right to fly designated routes with designated airlines. They are more complicated in some cases; for instance, if a small nation faces a large nation, say with one and several airlines in situ respectively, then the bilateral agreement might limit the large nation to use only one designated airline or allow several airlines to serve from the larger nation, but limit the places that they can use. This is often called 'gateway' designation. Basically, large (so-called 'international') airports might be gateways, although there is always pressured to remove constraints and to allow smaller (so-called 'regional') airports also to be served directly. This is happening more and more as the large airports are becoming constrained through their success, having created demand that has filled all the capacity they can offer. Capacity is an attribute of the air transport system that has been managed, overall successfully, through regulation, but the situation could be about to change. In that regard, bilateral agreements will begin to change too, which is a good example of how laws are never static. Overall consideration of how the air transport business works as a system will play a part in finding solutions to the issues that are arising.

2.9.3 Deregulation

'Deregulation' was a milestone in regulatory affairs. It took shape in the USA in the late 1970s, where a wide debate considered a plan that refuted the need for any traffic rights related regulation in the domestic sector. This concept saw the light of day on US statute books in 1980. Initially, US 'deregulation' applied to domestic operations only and all other aspects of air service regulation – access by international airlines, safety regulation, and so on – remained in place. Even so, it was an event that was to have worldwide repercussions.

Until 1980, in the USA all domestic airlines – as in all other nations at the time – had to hold a 'route license' for each service they operated. If airline A had pioneered and operated Seattle to San Francisco, they had the license for that route. If airline B decided it would like to operate the same service they had to apply for a route license. The license was only granted after a hearing, when the

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incumbent airline, and anyone else who had an interest in the case, could object and present their arguments. The USA prides enterprise and would often listen to an airline that was objecting to new competition with only limited compassion. However, if a route was being 'saturated' with many airlines (almost every airline wanted the most lucrative routes) the licensing body, the Civil Aeronautics Board (CAB), had to tread warily. It was becoming the norm to license two carriers on major routes and more on very busy routes, but the 'pioneer' on the route often won concessions from the CAB, whose policies were increasingly under scorn from new and vigorous airlines that saw the established carriers as feather-bedded, inefficient and overprotected. The major argument was about routes, but there was also concern that the CAB was too draconian in the way it set and administered fares across the US airline network.

'Deregulation' abolished the CAB. Airlines within the USA (and that was US domestic airlines only, as non-US airlines were, and still are, vigorously denied US internal domestic flying rights) were able to fly where and when they wanted. They could also charge whatever fares they wanted. It generated economic upheaval and many of the well-established airlines disappeared. The 'mega-carriers' – principally United and American – grew and grew, but they did this often by buying up small airlines, who wanted to be involved in the new era. Airlines such as Ozark, Piedmont and Frontier, which had gathered their own adherents, were swallowed and lost (in their original forms at least, as marketing forays have reintroduced the names recently in appropriate regions).

Most important of all, there was a new breed of airline. Initially they started with big plans, came on the scene, boomed or then flopped spectacularly, none perhaps more so than People Express, whose fleet, with intercontinental-range Boeing 747-100s and smaller types, flew the lowest cost domestic routes from the early 1980s. Some entrepreneurs attracted by the new opportunities decided to stage a quieter revolution and have set some of the most astonishing records of all. Most notable has been Southwest, an airline that pioneered the idea of a one-type fleet. However, they did not buy second-hand, but invested in the latest aircraft variants and built their business by offering the lowest fares in the hardest worked equipment on the continent. Other entrepreneurial developments included 'business-only' airlines – the other end of the demand spectrum – that offered widely spaced seats, at-seat service and premium fares, but none was really successful. Executives could use a business jet for little more cost and had additional flexibility in terms of when they flew and even where to. The business-only model does keep re-emerging, however, and its day may yet come.

Deregulation has been copied in Europe, with almost unhindered cabotage between all EU member states offered through successive stages of relaxation of the regulations. The aim has been to emphasize that Europe can be 'domestic' in nature, but for now the problems are manifold. With over two dozen countries and even with a common currency across many borders, there are adherents to the idea of a 'national airline' and to whom the thought that airlines that are almost household names could be swallowed by multi-national mergers is anathema. Europe now has some notable low-cost operators with hubs in many countries and has therefore pioneered the new paradigm, but the shifting sands are still moving at too great a pace to claim that a solution has been demonstrated.

It is not surprising to find that the same principles are being applied, often with great controversy, throughout Asia, Middle East, Africa, the Indian subcontinent, in Australasia and all around the Pacific. Nor is the concept unusual to the inhabitants of the former Soviet Union or China, where to see a commercial strategy driven by such blatant entrepreneurial flair would have been anathema in the harder days of totalitarian government. The consequence in all cases is exactly as it was in the USA, in that LCC operations emerge from locations that offer good 'hub' locations. The number of such airlines has multiplied rapidly since the year 2000 and there is virtually no country with more than one airport that now does not have an incumbent, or visiting, LCC.

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2.9.4 Privatization

The term 'privatization' is often lumped with 'deregulation'. It is not the same thing. Privatization is all about ownership, but what it does share with deregulation is the desire to press service providers to accept responsibility for investment and service issues, such as frequency of service and the quality aspects of whatever service is provided. Privatization is arguably a route to more public access.

In many nations, around the mid-20th century, there was a clamor to 'nationalize' all major businesses. This meant that the complete shareholding was acquired by the government, effectively using public money tobuy the assets of businesses that the public would use; thus, they would have 'ownership' and get the financial benefits that would otherwise go into private shareholders' pockets. Arguably, the sure-fire successes would mean that products were cheaper, and taxation was reduced. With some businesses it worked, but with others it did not, and transportation was one sector where historical records suggest that it was, decidedly, a bad choice.

Having businesses like airlines in government ownership tended to set their organizations in concrete. They were unable to accommodate changes in working practices – much as many of the managers involved certainly tried. Their profitability plummeted and doubt was cast on the service quality of their products. Governmental interference was always mooted, as the airline's owner was also the organization that was negotiating bilateral and other service agreements, and even the source of aircraft for the fleet. The USA was the only nation with a significant proportion of shareholder owned airlines conducting daily business, but even there the access to routes was restricted by bilateral agreements, and certain carriers – the erstwhile Pan American and Trans World Airlines (TWA) most notably – become the de facto 'public' airlines. Deregulation did introduce changes that lowered protection for such firms and the belief is that their lack of accountability was what led to their demise. This is deniable, but what is not deniable is that in Europe the majority of growth in the airline sector was with what were often referred to as 'independent' carriers. These were privately owned, often as offshoots from travel companies, and were operating lower-cost, albeit very specialist, charter services where it was felt that a 'privatized' market could treat as competition. More access to the market would encourage better practices and fares would tumble.

The push for privatization has led to the liberation of national airlines. British Airways (BA) was the first significant carrier to make the transition from nationalized to Shareholder Company, but there had not been an equivalent shift in any other EU nation up to early 2007. Many airlines have followed BA by attempting partial (rather than full) public ownership.

It has also been the way that airports and some service providers (especially air traffic control) have been forced to go, although in the latter case the UK example is being copied willingly, being a partial-privatization initiative. The government keeps a minority of the shareholding (49%) but has greater proportional representation on the board. This gives them, effectively, power over policy. In such stark terms it does not sound terribly democratic, but as later notes will show this is an area where change is inevitable and very significant shifts in emphasis in management are felt to be necessary. There will be considerable risk, certainly financially, and the fear is that operationally there is also a risk in accommodating such change. The government is there, in the model adopted, to shoulder responsibility on some thorny issues. Meanwhile, investors can be attracted too. It is notsurprising, perhaps, that when the bids were assessed the UK government chose to select a consortium of UK-based airlines to take the majority shareholding. The view is that, as customers, they know best the implications of bad management in the business. It will take a decade or more to find out if this is true, such are the interesting times in which we live. Airport privatization has been another on-going story. In the UK the major airports were owned by the government and operated through a nationalized business, called British Airports Authority (BAA). To some it seemed a license to print money, in that in the most prolific growth region, the south-east, BAA had almost all the capacity that was available ceded to its own organization. BAA was privatized around the same time as BA, as the airline – British Airways – chose to be defined. BAA chose to be called just that – no longer its original title – the argument being that it was not wholly British as it had acquired the assets of other airports worldwide. As these notes were being written it was swallowed by Spanish investment, becoming a part of the Ferro ailorganizations.

Most commercial airports were owned by local municipalities and were a limb of local government, but most major airports, and in some countries the majority of regional airports too, have been privatized. Those that have not undergone the change have been re-defined as a separate organization, owned or partially owned by the local government, but operated as a business that cannot inherit from, or contribute to, municipal funds.

However, some airlines and some airports, because of the uncertain nature of the business, especially when traffic levels are low, cannot be run as viable businesses. For example, they may support communities where a pure cost argument mitigates against their existence, but the benefits they bestow are so valuable in socioeconomic terms that they have to survive. In Europe the Norwegian government subsidizes airlines and airports that serve communities up and down the country's long and rugged, fjord ridden, coastline, and likewise in the UK the services of airlines and airports in the Scottish Highlands and Islands are subsidized by the government. These examples serve to remind the reader that 'one suit does not always fit all'. There has to be the capability to absorb flexible policy and to allow some variation in an otherwise dogmatically applied doctrine.

This section has dealt with the major issues that have determined the qualities required of those who have been involved in national economic regulation in recent decades. The other front on which national regulatory policy has to be handled in a circumspect manner is safety regulation.

2.10 Evolution

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The previously presented account of legislative issues has placed considerable stress on why the legislative system is never stagnant. By comparison, the operational infrastructure considered in this chapter, it has to be admitted, has been relatively static, in that what was used in the 1940s was still unaltered and in use 50 years later. However, in the last few decades the changes have been profound, and most of what was around in the 1940s and is still here today seems unlikely to remain either in a prime position or even to survive at all. Very radical change can be expected.

That change will arise from the exploitation of digital electronic developments. The whole of the operational infrastructure scoped in this chapter has depended on electronic systems development, and until the beginning of the 1970s that was almost wholly analogue technology, meaning it was based on electronic systems that used continuous signals (either radiated into space or passed along wires). Since the early 1970s the industry has developed systems that used pulsed, or digital, signals. The technology behind this is specialist and fascinating. Compared to the previous generation devices, digital systems tend to be smaller, more reliable and even cheaper. They can manipulate the pulses through electronic processors – microprocessors – that are familiar to all of modern society as the digital computer, which can be 'programmed' to do its job. While the equipment is hardware, the programs that reside within are its software. Some four decades have passed since digital technology began to affect the way that systems worked within the air transport operational environment, and it is

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now that we are on the threshold of seeing how it will reconfigure the environment. The changes in prospect are very profound.

Overall, it has become accepted that three elements make up the operational environment – communications, navigation and surveillance – which are referred to today as CNS. This nomenclature is used to structure the remainder of this chapter.

2.11 Communication, navigation and surveillance systems

The next few pages will look into current CNS technologies, considering individual 'systems', in terms of what information or capability they provide, but without considering their technical attributes in depth. Each is described in a way that will generate a better understanding of why it evolved, and what it has provided includes consideration of its operational strengths and weaknesses.

2.11.1 Communications (see Fig)

Wireless-telegraphy (w/t) and radiotelephony (r/t) are two ways of conveying information by wireless. The first system, w/t, is a wireless based version of the telegraphy system that was used throughout the 19th century, where messages were transmitted using discrete signals, such as the dashes and dots of the Morse code. The system was able to convey information through conditions of poor reception, and while it was bulky it needed less power than a voice-carrying system. These devices were used in the 1930s and phased out by about 1940. It can be argued that the discrete signal system is re-emerging with the advent of digital radio, and technology has a habit of recycling ideas, but modern discrete signal radios are used in a very different way.

The r/t system used a radio system that transmitted a voice message as a continuous signal. The signal characteristics were modulated at the transmitter in such a way that the receiver could reproduce the transmitted voice. This was used as radio broadcast in the 1920s, but needed huge transmitters, and it was only when compact radio systems that could be installed in aircraft were developed that the system arrived in aviation.

The very high frequency (VHF) radio is the continuous-signal radiotelephony (r/t) system that emerged in the 1940s. It met the need for air/ ground and air/air communications to be achieved using voice messages. VHF wavelengths propagate roughly according to line of sight (LOS), so the usable range is a function of aircraft altitude, although terrain can also play a part in terms of coverage. The system uses press-to-transmit (PTT) buttons, as only one user can transmit a message at any one time. When a radio system is used by a large number of aircraft, the ability to convey all messages and safety-related acknowledgements in a timely manner can limit the strategies open to users. VHF is widely used, but its limitations do impose constraints on operational capability in busy airspace regions. All VHF radio communications systems are installed under local aviation authority approval. (They can be eavesdropped by the public, but to transmit in the allocated frequency bands is a criminal offence.)



The high-frequency (HF) radio (see Fig. 4.2) has an operational utility that is broadly the same as VHF r/t, but the radio-wave propagation, which includes reflection from ionized molecular layers in the upper atmosphere, allows over-the-horizon (OTH) communication. HF r/t has become the



Commonplace system to use over oceans and sparsely populated areas and has held this role for over 50 years. The system has complex propagation characteristics, but the nuisance of unpredictable reception is a limitation that has been acceptable, given that traffic conflict situations are minimized in the airspace where it is used, so radio traffic needs are also reduced. If aircraft movements are more densely packed in remote skies the HF r/t system will become a limitation on strategic airspace utilization options. Like VHF systems, HF radio installations have to meet local aviation authority approval. An adjunct to the HF radio is a device called Secale (selective calling), which is installed on aircraft and will recognize a radio call carrying a short digital code that is unique to the aircraft. This allows crews on long-range operations to fly without their headsets; they respond to a chime from the Secale unit, which is emitted when a radio message is received.

The aircraft communication addressing and reporting system (ACARS) is a digital data link that uses a VHF radio system – hence LOS application only – but because it is digital and not analogue based, it conveys data and not voice. It has been implemented, appearing first in the late 1970s, and adopted slowly over 20-25 years to allow airline flight operation staff to communicate directly with active aircraft. ACARS is based on a ground-based receiver/transmitter network. An independent authority, Aric, installs the ground-based infrastructure and in so doing meets all statutory regulations and then operates the system on a commercial, non-profit making, basis. Thus, an aircraft anywhere with ground station coverage (almost all continental masses have been covered progressively since themid-1970s) can transmit digital data that will be received at a local ground station, and the destination address carried within the message will allow the data to reach the desired recipient(s) through the existing Aric-based ground telecommunications network. Such digital data-link technology (widely used in military service) has contributed to improved operational efficiency in airlines, but because the system is a subscription-only commercial system, it is not suitable for general operational use, e.g. by the ATC system. The system conveys digital messages that can fulfil a variety of operational needs, from delayed passenger booking details for commercial recipients to providing aircraft systems health data to engineers.

The secondary surveillance radar (SSR) is described later, under surveillance systems, but it is, in effect, a simple data-link and thus a communication system with less capacity but equivalent functionality to ACARS. Mode A/C transponders have been mandatory on aircraft in controlled airspace for some 50 years, and the latest transponder-based system, Mode S, has become mandatory in the majority of airspace in the last few years. Mode A/C was defined in such a way that it carried only two pieces of information – aircraft identity (Mode A) and aircraft level (Mode C). Mode S is

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functionally similar to the ACARS system, as it is able to carry bursts of digital data that can convey complex messages. It is suited for conveying ATC-based messages, as SSR installations are rigorously regulated under the auspices of ATC service providers. The SSR is a digital message relay system and does not carry voice messages.

Autonomous dependent surveillance (ADS) is a system introduced relatively recently that is named, and extolled, for its surveillance attributes. Rather like ACARS it is a general-purpose digital datalink system, but this time it uses satellite transmitters/receivers and has worldwide coverage; it is a non-commercial service. There are three types of ADS and these are being evaluated and developed at the time of writing, the first operational exploitations having been explored over the Pacific Ocean in the late 1990s. Initial applications are as a unit to convey aircraft position and flight path information – hence the 'surveillance' title – but the greater data capability will be used in due course. This is the justification for describing it as a communication system. ADS seems likely to be the most commonly used system to transmit/receive digital messages in long-haul operations by 2010 and could be introduced rapidly in shorter-range operations, thus becoming the dominant communication system in the 2015–2020 period.

In summary, the communication scene, which was almost unchanged for some 50 years, has suddenly begun to change and the leading developments have been in SSR and ADS systems. Their capabilities are yet to be fully proven, but limited-scale evaluations (Project Capstone in Alaska has been a very notable demonstration of what ADS can achieve) leave little doubt that these are the communication systems of the future. ACARS has become well



Established and its impact in the commercial sector is a lesson for the noncommercial sector. The VHF r/t radio has been 'overhauled' in recent times, with digital transmission replacing analogue in prospect, which brings reception and cost benefits; this may be the way ahead in the voice communication sector. The digital data-link seems certain to develop a new set of applications as it will allow computers to talk to computers. Mode S/ SSR and ADS are poised to make the future communication systems field unrecognizable to those familiar only with r/t and elementary SSR applications. Radio communication on the flight deck is shown in Fig. 4.3. The next section takes an equivalent look at navigation systems.

2.11.2 Navigation

The radio range was the first enroot radio nevoid in civil aviation and was withdrawn from use by the 1960s. The device set some operating concepts that are a legacy and make a useful stepping-off point in this review of systems. It required a ground-based transmitter and an airborne receiver with a directionally sensitive antenna. The transmitter worked in a radio band that has been largely abandoned by the aviation community (the next system, NDB, being the only device that still operates in the same waveband). It created a number of sectors (or lobes) within which there were different Morse code messages (an A (dot–dash) or an N (dash–dot)), and the antenna configuration allowed them to overlap at their edges. The aerial could be adjusted to make the overlap occur in four directions from a ground station, or beacon. These were detectable by an aircrew with a



receiver as a Morse signal at the edges of the overlapping course, where the signal was continuous. The crew could thus be guided to fly to/from a ground beacon and this capability led to ATC clearing aircraft to fly routes that were defined by successive radio stations. They were usually about 70-80 miles apart, representing about 30 minutes flying time in 1930s aero planes. They were usurped by the VOR, which is described later.

The non-directional beacon (NDB) (or automatic direction finder (ADF) for the on-board component) is the only navigation system that survives from the 1930s era. It is not recognized in regulations as sufficiently reliable for primary navigation use in civil aviation, but with many thousands of beacons available, most airliners still carry an ADF receiver and will use it to cross-check other navigation systems or to provide pre-visual clearance to an airport. In this application the system is often called a locator. It has survived even though it suffers from interference and when it provides guidance towards a beacon it does not state the direction from which it is approaching. In this regard, it is no different to a light beacon (or maritime lighthouse), but it can be received in all weather conditions (interference permitting). It is cheap, reliable, easy to install and maintain, and requires little power. All installations still require regulatory authority approval.

The VHF omni-directional range (VOR) (beacon) emerged in the 1940s as the navigation aid that could usurp the NDB and the radio range. It is interference-free and does provide an indication of course when flying to orfrom a beacon. Many thousands are installed worldwide, and they are still the main source of radio-position fixing used by most airliners and all other commercial aircraft. They are

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numerous because they have been supported as the preferred ground beacon by ICAO since the late 1940s. The VOR uses the VHF radio (hence it is LOS and almost interference-free), but compared with the NDB, the ground stations are more expensive and as reliable, but fussier about terrain and objects near their site. They are complex units and can be described as a radio-based lighthouse, which emits not just an identifiable beam but a signal that has strength (radio amplitude) and colour (radio frequency) variations that a receiving unit can differentiate in order to determine their precise bearing from the ground station. This means that an air route between beacons can be aligned in any direction and a crew (even an autopilot) can select a course (called a radial) that they are guided to fly precisely. The ground stations are expensive to maintain, and installations must be under close supervision, with appropriately qualified staff involved. This is almost a disadvantage, as the army of radio technicians needed to maintain a nation-wide system of VORs is often a large burden on airspace service providers. The VOR faces an uncertain future, because of its cost of ownership for the operator.

The distance measuring equipment (DME) is a radio device that will indicate on a numerical read-out the distance to the ground station (within LOS) operating on the appropriately selected radio frequency. The VOR and DME are often co-located on the ground. The DME has been collocated with VOR and ILS (to be described) and has gained popularity over the last 50 years. Initially DME receivers were very expensive, but their cost has reduced greatly since the late 1970s. It is therefore widely used and it is possible that, while DME installations will decline in number if VORs are removed from service, many installations may survive for the simple reason that this is a device that may have a 'new role' as the newer navigation aids come on stream. There is not a great deal to say with certainty about the system's future, but it does not appear to be quite so bleak as that of the once all-pervading VOR.

Area-navigation (R-Nav) systems are enigmatic, because what were RNav systems have disappeared and what has replaced them is said to have R-Nav capability. This paragraph is concerned solely with now defunct systems that form a legacy. The most successful systems were developed to guide bomber crews in the early 1940s and the systems that survived as commercial systems were Loran (long-range navigation) and Decca Navigator (a proprietary system owned by the UK company of the same name). They used a set of ground-based stations, typical four units with one master and three slave stations, which emitted HF radiation and were thus receivable beyond LOS. The ground stations were linked by land lines that ensured signals from the slaves were coordinated in time with signals from the master; all four radio stations had a dedicated radio frequency and the receiver had to be able to collect the information from all four. The relationship between the master and one slave created a pattern that was a series of hyperbolic lines aligned perpendicularly to the line between the two stations. (The only way to appreciate this relatively complex situation is to imagine two pebbles dropped into a pond and to watch the ripples expand from each point. If the pebbles are dropped at the same instant in time the ripples will meet at the mid-point, and as they overlap, the point of intersection will be a straight line perpendicular to the line between the points where the pebbles entered the water. If the pebbles are not dropped simultaneously the ripples will meet at a different point and the intersection of the ripples will extend from that point as a hyperbolic line.) Loran and Decca receivers in the 1950s and 1960s were only able to provide a set of numbers that a navigator had to interpret and plot on a chart. There were some charts that could be mounted on a carriage and stepper motors moved a stylus to the aircraft's position, but the mechanical nature of these required that the map was 'distorted' and flying a straight line generated a curved line on the chart. This stopped the systems in their tracks; they were overtaken by more user-friendly devices (such as INS).

Even so, hyperbolic systems have been gradually usurped. The last Decca station was withdrawn from service in the 1990s and Loran has been under threat of closure since 1990. They have deserved

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mention because their legacy is immense, as will become evident when satellite-based navigation systems are considered.

The instrument landing system (ILS) is a highly directional guidance system with horizontal and vertical guidance components (called a localizer and a glideslope) that provide precision guidance down a glide path (typically from 20 nm or less distance) to the runway. It was developed in the late 1940s and accepted widely almost immediately. Compared with the only option at the time, which was a radio talk-down from a radar controller on the ground, the system was very cost-effective. A talk-down system could only handle one aircraft at once, or more if there were more workstations and controllers, but both solutions were expensive and had runway approach capacity implications. The ILS remains available at many leading airports, often with several ILS installations at each airport, with one for each runway and each runway end. It provides 'straight-in' guidance, at one glide path angle only (which is rarely a problem), and it is reasonably interference free. The radio frequencies allocated to the system are in demand for other uses, so the World Telecommunication Union (WTU) keeps indicating that it cannot protect the ILS radio wavelength spectrum forever. The ILS is a system whose days are almost certainly numbered, but as yet a replacement has not emerged.

The microwave landing system (MLS) was supposed to be the successor tothe ILS. Its signals can be interpreted to guide an aircraft in a similar manner to the ILS (i.e. on a straight course and at a predetermined glide path angle) or it can be used to guide an aircraft on any three-dimensional path in a wedge-shaped sector that is based on the touchdown point. It is rarely seen, however, as airlines and airports have not seen fit to invest in this system. The specification for the MLS was released in the early 1970s and its development occupied almost a decade, which had it ready in time for widescale use by 1990 and the complete replacement of the ILS by 1995. Nowadays, a license to manufacture the MLS is almost an embarrassment. This is an example of where technological acumen was difficult to judge and proved expensive for those who accepted the challenge. The emergence of satellite-based navigation systems in the 1990s was not unexpected, but the scale of the new system's dominance was a surprise. The MLS has been the most notable aviation casualty.

Omega was a codename that was adopted as the system name. It was a worldwide system, created and run exclusively by the US Department of Defense (DoD), which evolved in the 1960s, saw its heyday in the 1980s and was withdrawn from use before the end of the century. The system used very low-frequency (VLF) radio signals. These required massive transmitting antennas (because the wavelengths were several tens of kilometers) and were valuable to the military because of the socalled 'ground-wave' propagation that provided long-range coverage and permeated water, allowing the signal to be received by a covert nuclear-powered submarine while it was submerged. The receiving antenna was small and had aeronautical applications. In principle it used the same techniques as the R-Nav systems that have already been described - Loran and Decca. Instead of having a chain with a master and three slaves that would serve a region, Omega had nine transmitters that were sequenced in time, and instead of being landline connected to synchronize their transmissions, they used an atomic clock. The system promised 5-nm position-fixing accuracy worldwide, and while over much of the Earth's surface this was bettered by a substantial margin, in some places the propagation was poor and system usage was fraught with difficulties. By the mid-1990s GPS (the next system) was available and could outperform Omega, so the DoD switched off the stations, rendering all Omega receivers useless. This action, alongside a continuing expression of intent to turn off Loran systems, has been behind the skeptical views on US DoD ownership of GPS.

The global positioning system (or just GPS) is an acronym that has been synonymous with the way that satellite navigation (satnav) has developed, but it was simply the first all-encompassing system (in that military-only systems such as Transit were around in the 1960s). There are other systems and

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more are coming. GPS (originally called Navistar) emerged from a series of US military satellitenavigation developments that started their operational life in the 1960s. It was expected to serve the military by the mid-1990s and its influence on civil operations was not overlooked, but its utility was diminished by the imposition of signal signatures that did not allow civil users to obtain the full benefits of GPS. It was said, in the late 1980s, that GPS would provide a 50% probability of position error of 5 meters in the military (precision) mode and 200 meters or better in the civil (coarse) mode. It needed a 'constellation' of 18 satellites, six spaced in three orbits with about a 12-hour orbital period to be fully operational, as a user must be able to view at least four satellites at any point in time to determine the precise position (in three dimensions). As more and more satellites were inserted into orbit the system showed that it would live up to, or even surpass, its promised level of performance, although the satellite constellation grew from 18 to 24. Intrinsically, GPS is like Omega, in that the satellite transmissions are synchronized using an atomic clock, but this is not carried from place to place any more. Periodic monitoring is conducted on every satellite at very frequent intervals (a few hours apart) and the receiver determines position by interpreting the time relationship of incoming radio pulses. The legacy of Loran and Decca, through Omega, hence, lives on.

Conflict in the Middle East in late-1990 led to an acceleration of deployment and the military commanders were so keen to equip ground vehicles and troops that civil receivers were used, so for a while the precision code was accessible to civilian users. At about the same time, the ICAO Future Air Navigation Systems (FANS) panel published its vision of the attributes of a future navigation system and GPS was able to meet all the criteria, with one exception. There was no assurance from the US military authorities that the system had the 'integrity' that was needed. If it experienced a failure, and many kinds of failures could be postulated, would there be palliatives to protect users? Above all, in the event of conflict, would the US turn off the GPS system? In the early 1990s the US DoD submitted its own failure case analyses to ICAO, which hinged largely on describing the, until then, highly classified way in which the monitoring of satellite performance was conducted. These were assurances that silenced the critics. They had, by then, also announced two significant GPS-related system developments, called the wide-area augmentation system (WAAS) and the local-area augmentation system (LAAS).

These two systems were designed to allow civil users to obtain more precise position measurement from the satellite navigation system. An application that had emerged already was called differential-GPS (D-GPS) and was designed principally for surveyors. If a GPS receiver was located at a known position, it would derive position from GPS and thus derive also a measure of the GPS error. If that was replicated in the area, then applying that error to all GPS position data would provide the precise position. The WAAS concept envisaged doing this in a manner that would allow the error



data to be communicated by radio data-link. (It is necessary to measure the error from different combinations of satellites and to provide a tabulation of errors so that a user can correlate position with the appropriate satellite combination.) WAAS was put into trial in the late 1990s, certification was expected to be straightforward and LAAS was slated to be approved in time for full use in 2010. The latter system was almost airport-based and was so precise that it could do the job expected of the MLS, thus causing the loss of interest in the earlier system. In the event, WAAS certification was much more difficult than anticipated and the programme has slipped. However, WAAS precision is so good that there is a strong feeling that LAAS will not be necessary. This is still not confirmed.

For stages in the evolution of satellite-based navigation systems see Fig.

The US took the lead in satellite navigation (Satnav) and the rest of the world was not willing to watch or to depend on them. The Soviet Union started a project called Gleans in the 1980s. This has been sustained, albeit with less tempo, by Russia, and provides satellite navigation from an independent source. Europe has opted to develop a third system, called Galileo, which will become operational towards the end of the current decade (by 2010) as satellites are launched, often several at a time. (It was discovered recently that they are often using Russian rockets.) There is a Chinese system in prospect as well.

By now, there is a comprehensive set of Satnav systems, all able to meet ICAO criteria in terms of availability, accuracy and integrity. It seems likely that this will be the case for the foreseeable future and question marks aretherefore placed over the future of all the systems already described. Will NDB, VOR, DME, ILS and MLS all succumb to the superiority of a set of Satnav systems? These super-accurate systems offer the same fidelity almost anywhere on the Earth's surface – whether over oceans or deserts, or near the physical or magnetic poles. In all locations high-accuracy position-fixing is almost guaranteed. Within the organizations that supply navigation data to civil aviation, this is the big question. It has crept up on the industry so suddenly that it is still, metaphorically, in the process of taking a deep breath. Much of what follows in subsequent chapters outlines what the industry must evaluate.

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Navigation is a broad area to describe. The narrative so far has looked at the lessons learned from the rise and fall of many systems that have been in service and then withdrawn, with system extinctions peaking as the GPS began to show its capability in the last decade or so. However, a set of more autonomous – non-radio – systems has been and continues to be used widely. There is little evidence that their usage will diminish, and some theoreticians think they could be more numerous than ever in the future. Their story requires a brief entry at this stage.

The inertial navigation system (INS) was devised by the military in the 1950s, initially to steer guided missiles, and then it was adapted for manned aircraft use. It was selected because it is an autonomous system and thus neither emits signals nor depends on radio emissions. It was first used on airlines in the late 1960s and was the standard navigation system on all long-haul aircraft in production within a mere five years. It used a gyro-stabilized platform on which was mounted a set of accelerometers. Before take-off the accelerometers were aligned north/south, east/west and vertically, and the latitude and longitude of a reference point at the departure airfield was entered into the system's computer. As the aircraft flew its route, the system monitored accelerations along each of the three axes and a computer converted these (a double-integral in mathematical terms) into distance covered, doing so with sufficient accuracy to surpass the performance of any human navigator. The equipment was expensive, but from that day on the navigator's days on long-range airliners were numbered. In general, system navigation errors, which grew with time, were around 0.5 to 1.0 naut. miles per hour. At the end of a trans-Atlantic crossing an INS set could deliver an aircraft to a point which, with a high probability, was within the destination airport boundary fence.

The laser INS (LINS) is a logical development of the INS, as in this device the mechanical gyroscopic stabilization is replaced by solid-state laser ring gyro (LRG) units. The system now operates with no moving parts, so it has improved reliability and is even cheaper than the INS to own and operate. Nowadays airlines often have combined LINS/GPS sets. The reason for combining these two navigation systems is that they have dissimilar failuremodes and error characteristics, so each complements the other very well. (This is an example of a 'systems' solution where it can be argued that 'the whole is greater than the two halves', but more about these later.)

Note that on a long-haul aircraft one might expect to find three such units, which are all cross monitored. Thus, the failure of any one is recognizable, so it can be disconnected, and the aircraft can continue on its way without any significant impact on the level of attainable safety. This accords with the failure-case criteria that are exemplified in the risk assessment part of safety regulation.

Summarizing the current navigation system situation soon reveals that this is a turning point in the history of the subject. That is true in aviation as well as in many other sectors, such as transportation, surveying, timetabling/scheduling where Satnav has poked its fingers and won first place over all comers. If this author feels challenged, especially in the breadth of issues that are being addressed in this review of the air transport system, it is in knowing where to cast the net in regard to where Satnav will influence solutions to forthcoming system issues. Within this section itself, when commercial operational infrastructure is discussed, do not be surprised to find that the eponymous Satnav systems work their way into the debate again and again.

It is time to consider the third, and final, element of CNS systems.

2.11.3 Surveillance

A radar or 'primary' radar (to distinguish it from a secondary surveillance radar (SSR), which follows) is a radio-detection device, the principles of which were proven in the late 1930s. There are many kinds of 'radar', all used in aviation – weather radar, interception radar, height-finding radar,

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etc. – but in respect of the air transport system, only ground-based surveillance radar will be considered. Radar is a 'line of sight' system (roughly) that detects objects in the area swept by its narrow, rotating, beam by detecting reflected electromagnetic energy. The bearing of an object is determined from the beam position and the range is determined by the time taken for energy to return to the radar station. ATC surveillance radar will typically detect airliners from 20 to 150 naut. mile maximum range, the absolute range being determined by the power transmitted and the application for which the radar is employed.

Throughout development from the 1960s radar has been integrated with the digital computer, in what is often called a radar data-processing (RDP) system. This is a way of extracting position from a radar, or a set of radars, and of developing each return into a 'plot' that can be shown at a position on a display system. (The circular 'rotating strobe' form of display is not nearly as common in ATC workplaces as it is in movie renditions.)

The secondary surveillance radar (SSR) was introduced in Section 4.3.1 on communications, as it is the ground element of the ATC transponder. The ground-based interrogator, which is mounted on a radar-like rotating structure (and will often be mounted on the same 'head' as a primary radar), emits pairs of pulses that trigger a 12-pulse Mode A (code) or Mode C (altitude) response from the aircraft's transponder.

Mode A is a four-number code, each number having a value from 0 to 7 only; thus 0000 is the lowest and 7777 is the highest numerical value that can be transmitted by an aircraft. There are 4096 possible combinations in total. The aircraft crew can set the code on a flight-deck panel and will be allocated a code (called a 'squawk') by the ATC.

Mode C uses the same 4096 code system as Mode A, but the 'framing' pulses are at a different time separation and the pulses this time are created from an encoder on the aircraft altimeter, such that the transponder conveys the altimeter reading to the interrogator on the ground.

Mode S interrogation and transponder systems are a third version of SSR and are in the process of being commissioned. These will allow up to 128 bits of information to be exchanged both ways between the ground and aircraft, which will almost certainly be the preferred digital data-link system for ATC service providers in the near future. A Mode S compatible transponder is already mandatory for all commercial aircraft, in virtually all controlled airspace, throughout much of the world.

The SSR uses similar codes and frequencies to the military Identification Friend or Foe (IFF) system. This accounts for the missing Mode B and is why the SSR is sometimes referred to as the IFF. Aircraft nowadays have an on-board low-power ATC transponder interrogator that will trigger responses from nearby aircraft. This is the primary information sensor for the TCAS, a system that will be encountered later.

Autonomous dependent surveillance (ADS) has already been mentioned in Section 4.3.1 on communications as it is really a communication link, but the information it will convey includes aircraft position, so when it carries this information it is effectively a surveillance (position-detecting) device. Trials commenced in the late 1990s and it is anticipated that the system will quickly be accepted as the prime source of position information for aircraft that are flying over oceans and unpopulated areas; it could also become the primary communication device overall in the fullness of time.

As the summary presented in Section 4.3.1 on communications showed, there is some doubt as to whether ADS or the Mode S transponder will be the preferred data-link solution of the future. Mode S

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requires a ground station and it will almost certainly dominate in certain regions. ADS, however, is available worldwide and will dominate over oceans and sparsely populated areas. Hence, the final solution might almost certainly be a combination of ADS and Mode S. By having a combination, there is lesslikelihood of a common failure causing total communication system breakdown. This is repeating the story presented in the case of INS/GPS and upholds the safety case risk-assessment techniques discussed in Chapter 3. Systemic solutions appear through such justification. They have to be justifiable – they cannot arise simply from an idea.

2.12 The airborne elements

The CNS system elements already described have done much to stimulate change on the airliner flight deck – so much so that pilots whose careers spanned the 1940s to the 1970s saw tremendous change. In that period, the typical crew complement fell from five to three, and the systems they operated were often radically different. Since around 1982, when the first two-place flight deck rolled from a production line the overall configuration has changed little, but the roles performed by the crew members have changed a great deal. In the future, the changes could be even more radical, because while aircrew were once virtually as remote as desert-island stranded survivors, nowadays they can be bombarded with communications. Aircrews are aware of the changes that will occur and keen to ensure that safety-consciousness is maintained. They look towards the flight deck of the future where a crew will be genuinely assisted, not just monitored, as they accept an ever-increasing heap of responsibilities.

In reviewing flight deck developments a roughly chronological approach is used to guide the narrative, respecting how technology, needs and implementations coincided. The aim is to provide a key to understanding how the developments currently being revealed can be expected to impact air operations in the future.

Up to about 1960 avionic systems were developed by specialist companies, each developing a saleable product that was self-contained. The aircraft was offered to a customer (airline), who was free to specify the majority of equipment to be installed. This meant that few systems connected at any stage with any other system. Each supplier bought-in or built their own sensors, developed electronic processing units (usually analogue technology) and also manufactured small control panels, as well as their own instruments. Because they were customized to the customer's needs, the systems were expensive to maintain. The typical flight deck was 'cluttered' and human–machine interface issues (as accident reports from that era testify) plagued operations.

If an airline bought a second-hand aircraft, although externally the aircraft might look identical to other examples already owned, it was inevitable that the systems would be very different. The cost of re-equipping aircraft was excessive, which was one reason why aircraft were often scrapped after only a few years in service. Airlines appreciated that 'standardization' would bring several benefits, such as:

- common installation from different manufacturers, which meant that customers had greater choice and the better supplier could usurp less capable competitors
- by corollary, the manufacturers had to offer better value for money
- systems could exchange information (because the interfaces were standardized)
- Common installation standards led to simplified production, meaning that costs were reduced.

These are system attributes that happen to meet financial, safety, efficiency and effectiveness criteria.

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Standard-sized instruments and standard-sized processing units (by now called avionics) allowed installations and data interfaces to be defined precisely. This meant that if a supplier went out of business, their equipment could be replaced by another supplier's equipment, or data could be exchanged or integrated within display units, thus reducing flight deck 'clutter'. The commonality standards were addressed as 'form, fit and function' compatibilities.

Flight deck layouts evolved with a more regular set of instruments and control panels, often hiding the fact that the aircraft systems controls were still complex and needed to be continuously monitored. Therefore, while the radio operator and the navigation functions were eliminated, for a number of years a flight engineer sat behind the two pilots.

The surge in advancements that has been attributed to 'generations' of technology took a significant leap when, around 1970, digital electronics began to replace analogue devices. At this point very deliberate 'integration' began and the most notable development was the data-bus, which is a very high capacity digital data-transfer system. Systems could use the same, or a set of common specification, data-transfer systems, and thus any information from any unit could be made available to any processing unit, any processed data were available for any display system, and so on. The companies making 'instruments' or 'radios' in the 1950s had become systems integrators by the 1970s. The major principles of business were also upheld:

- These devices led to lower cost of ownership (although they were more expensive to buy, they needed one less crew member, as the flight engineer now disappeared).
- They were intrinsically safer, in that information could be shared and disparities almost eliminated (but this was a trend that had to be applied judiciously).
- They used processing capability efficiently.
- They offered ease of operation and cost benefits that the users wanted.

The most important issue at stake was the fear that one failure, or an inadvertent misuse, would have a catastrophic effect on operational capability. The reduction of the possibility of such an instance, to the point that it becomes an 'acceptable' failure in risk assessment terms, is essential in systems design and development work. Much of significance has happened that is non-CNS related. For example, fuel and 'utilities' management systems and automated flight control systems (AFCS) – at one time the humble 'autopilot' – have all witnessed changes in their configurations that have had an impact on the crew interfaces. Indeed, overall, the crew interface on a modern flight deck has been trusted to a diminishing number of highly integrated systems, such as:

- the automatic flight control system (AFCS)
- the flight management systems (FMS)
- the electronic flight instrumentation systems (EFIS) and
- the electronic centralized aircraft monitoring (ECAM) or engine instrumentation and centralized aircraft system (EICAS).

New sensor systems have contributed greatly to safety, especially in a workplace, where the time that can be devoted to monitoring has been diminished. These have included:

- ground-proximity warning systems (GPWS)
- the later enhanced GPWS (EGPWS)
- traffic conflict-alerting system (TCAS) and
- Radio-baseddatalinks, such as Mode S transponders and autonomous dependent surveillance (ADS).

In the next few pages a review of these devices is presented. There is no apology that the actual operation of these complex devices is not delved into at button and indicator level. The aim is to present a clear impression of what can be achieved when integration is not just preached but is practiced. The issues that spurred these advancements were entirely in tune with the creed already espoused, that cost-effectiveness, safety and efficient operational outcomes were the essential drivers. A point to stress is that this is a race that began as described here and that it is still not fully run. A schematic of a modern flight deck is shown is Fig.

2.12.1 Automatic flight control system

The automatic flight control system (AFCS) grew from the so-called 'autopilot' (affectionately called 'George'), which was installed in longendurance military bombers. The device would hold a steady course and sometimes a steady altitude, thus relieving the crew of the need to maintain control throughout long periods of cruising flight. The 'civilianized' equivalent – indeed, a few civil aircraft had crude autopilots before their military application – allowed a crew to 'dial-in' heading, altitude, rate of climb/descent and, when engine control was added, aircraft speed. What intensive usage in military operations had revealed was that the system needed to be monitored by the crew, as it was a safety-critical system with major, and sometimes potentially hazardous, failure modes.



Post-1945 AFCS designs had expanded capabilities and came with a combined instrumentation package with a flight director (FD) system, which added mechanical symbology to the artificial horizon instrument, placed 'bugs' on the airspeed indicator and compass displays that showed selected values, and so on. Within the AFCS/FD manufacturing community different 'styles' of display and control evolved, although the principles were all similar. By the time jet-powered airliners were entering service the AFCS (still called autopilot in some references, but this term has been relegated since to describe simpler systems) was already integrated with the radio naiads, such as VOR and ILS, and later DME, so that a course could be selected and flown with the system taking care of cross-wind drift. The time to-go to waypoints was easier for a crew to compute as they could monitor the situation all the time.

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There was a price to pay; as the systems became so crucial to achievingdaily service reliability targets and for moderating the crew workload after the navigator and radio engineer had been automated off the flight-deck most AFCS installations had two channels. They would be monitored independently by the two pilots and discrepancies used to detect 'failures. This did not deter manufacturers from including built-in test (BIT) systems, and if these issued a warning before the crew had detected an error, the warning often assisted a crew to decide which channel they should trust. They had plenty of other monitoring options and a competent crew could detect unacceptable AFCS performance (a gentle 'runaway' was the most insidious, when an attitude or flight-trajectory datum began to change imperceptibly and was only detectable after a sizeable error had been achieved). The AFCS thus became cemented into the jet airliner flight deck. Around the 1960s its controls were usually in the center console, just behind the throttle levers, but as the system's usage grew in importance the controls were developed as an elongated control panel that could sit on the center coaming, where it occupied a spot that for decades had been devoted to engine fire indicators and extinguisher controls. The engines were now more reliable and the AFCS was important enough to take this prime spot.

The most capable AFCS systems became multiplexed, with triple or quadruple channel configurations. Whereas earlier systems had been able to fly an aircraft down the approach, with the crew hands-off until decision height, the newer systems could be trusted to perform an automaticlanding. This was not just engineering bravado. This was a capability that could assure an airline of service reliability in almost any low-visibility weather conditions (which in the 1960s were becoming embarrassingly commonplace). The systems included self-monitoring, usually with 'majority-vote' concept comparators, and thus a three-channel system could survive a single-channel failure. The four-channel systems used were so-called 'duo duplex' with equivalent failure-survival modes. These systems, using ILS (or more lately GPS) guidance, with a radio altimeter to assess height, allowed fully automatic landings to take place in even the most severe conditions of low cloud base and visibility. The so-called Category 3 (Cat 3) system, which needed equivalent failure-survivability built into the ground-based radio guidance system and astonishingly complex aerodrome lighting systems (described in Chapter 7) will allow a crew to land with a zero-foot decision height (DH) and in visibility conditions, expressed as runway visual range (RVR) conditions, below 300 meters to as low as 75 meters.

Most AFCS technology was developed using analogue computing and the basic concepts remained unchanged, but the implementation changed radically as the digital electronic generation emerged. Whereas separate roll, pitch and yaw 'channels' were built into each control channel in the analogue era, in the digital computer these could be handled by time-slicing, or time-sharing, the computing element in a single channel. The AFCSbecame lighter and the individual units within the system tended to become more reliable. The biggest drawback of the 1970s designs was that the flight director system, which had attitude director indicator (ADI) – in effect a complex artificial horizon – and horizontal situation indicator (HSI) components that were still electromechanical, could fail to display what was being detected within the system.

In terms of the human-machine interface, the displays that are used by a crew have to be as effective as the controls at their disposal. A stunning failure example of the era was the catastrophic failure of the liquid oxygen tank on the Apollo 13 lunar space mission, which so nearly led to the loss of the crew. The system that failed had been damaged, and subsequently repaired, after it had overheated many weeks before it was launched, but because the temperature sensor recorded only up to the highest expected normal temperature value, the severity of the event had been unrecorded and went unnoticed. Within the system the damage was substantial, but that was not evident until failure occurred. There are many equivalent examples in civil aircraft operations of instances where crews have been given erroneous, or misleading, sensor information that has not been recognized, and has been irrelevant in operations in general, but has become the most critical seed at the root of a chain of events that have led to a disaster.

2.12.2 Performance management systems

Performance management systems (PMS) formed a transitory unit, but it set a precedent that deserves a mention. A crew could deduce, but often could not articulate because they lacked the time needed to consider, how wind, air temperature, aircraft mass and other variables would influence performance. The PMS was a computer that was hooked into the appropriate aircraft sensors and could carry out performance calculations at the touch of a button. It could advise a crew when to request an altitude change, assess the fuel penalty of a non-optimal cruise clearance, and so on. The firms that developed these systems were often small companies, aware of new opportunities, and they were galvanized to offer a worthwhile development to aircraft operators when the fuel crisis of 1973 bit deep into the financial performance of many airlines. Their devices were not universally accepted, however, as they were expensive to install (needing so much linking to many sensors) and difficult to incorporate in any aircraft. The PMS supplier also faced difficulties because almost every aircraft had systems that differed subtly from each other in certain ways. Each aircraft installation was a major integration task, with different implementations applied across similar aircraft types that were used by different operators. Systems integration was a major headache and those who had bitten thechallenging bullet that PMS represented were often bankrupt before they had started to deliver the product, because they had, unsuspectingly, entered a minefield. A lucky few were absorbed, through mergers and takeovers, into larger firms, and some really talented entrepreneurs shifted their gaze to the less susceptible business-jet and general aviation markets and succeeded quietly in that field. It pays to be brave occasionally, but the risk in a commercial sense is often more hazardous to affirm than the technical risk.

The solution to the integration problems was the data-bus, which had been introduced around 1970 (the Boeing 747 being the first aircraft to use the Aric 429 data-bus system from its service entry date). Even though it was a very lack-luster system, in terms of operating capacity, it was the major system for 'standardization'. Its limitations were largely because regulators were risk-averse and stuck to an implementation that was achievable using mid-1960s electronics technology. It was not an unwise decision, but their choice was under scrutiny and faced criticism at the time. This is indicative of the dilemmas that face a designer in a high-technology industry where the working parameters are moving rapidly. Aric 429 was 20000 bits per second specification, drafted in the late 1960s. It assumed the use of 32-bit digital 'words' and thus could convey around 500 words per second. It offered terrific performance in its era, but by 1973, when Aric was reviewing all equipment specifications to harmonies data interfaces, it did not go unnoticed that the US military had adopted a data-bus technology, called Mil-Std-1553, that achieved 1 million bits per second and used 16-bit 'words', thus intrinsically offering over 50000 words per second. Nowadays even these rates are regarded as 'pedestrian' in widely available commercial products such as multi-user computer games, and no doubt the rise in 'bandwidth' in such applications has much more yet to offer.

Nevertheless, the die was cast and from the mid-1970s commercial aircraft systems were being designed to make best use of these 500 words per second technology. The digital flight deck would be radically different to that of previous-generation aircraft, largely on account of three developments:

- electronic monitoring and control of on-board aircraft systems
- electronic displays (replacing the electromechanical displays)

• the flight management system (FMS), which usurped PMS.

A consequence of these changes was the ability to design an airliner with such well-harmonized display and control interfaces to the crew that the flight engineer was no longer needed. The two-place crew compartment was heralded by Boeing on the 757 and 767 airliners and on the Airbus A310. They were based on the same equipment specifications (Aric 700 series) and by offering three aircraft types with almost commonality of all sensors and many control and display components, these airliners allowed the equipment manufacturers to see a financially sustainable product development programme. The sheer scale of the development of these systems was daunting to some firms and in the end only a handful of them, almost all conglomerated in some way, has survived to develop modern aircraft systems today.

A brief account of the attributes of the main systems is given below.

2.12.3 Electronic control and monitoring or engine instrumentation and central automated systems

This system manifested its presence on the new aircraft as electronic cathode-ray tube (CRT) display screens in the center of the main instrument panel. The screens provided information and enabled a crew to monitor systems. This meant that what had occupied a sizeable amount of space on the flight engineer's panel in the rear of the flight deck on previous aircraft types was compressed to two screens that were relatively small. The system did this by having 'multi-function' screens, with 'pages' devoted to systems, such as fuel, electrics, hydraulics and environmental control. If all was well, the pages would be blank. In the most common implementation, the 'default' screen shows engine instrumentation data, and in recent times the CRTs have been superseded by liquid crystal display (LCD) units, which are lighter and more reliable.

Behind the displays a computing element takes in all the systems data (not always on Aric 429 interfaces) and compares, using software, the value of each parameter with a scale that categorizes it as green, amber or red, for okay, of concern and out of range respectively. The computer is doing what the flight engineer used to do. If the results are green, the system display shows nothing, but if a warning is appropriate the system can activate an attention-getting annunciation (usually on a small panel adjacent to the ADI and thus within each crewman's primary field of view) and the display 'page' for that is shown immediately. The parameter values are color-coded, so unacceptable values can be seen immediately by the crew, who exercise control via control units on the overhead panel. These are arranged in a schematic diagram fashion and the lights that display the status of control effectors (pumps, valves, switches, etc.) are arranged to illuminate only if they need the crew's attention. Getting all of this into such a small space and leaving the crew free to make decisions and take actions with confidence about the outcomes has been paramount to making the transition from three-place to two-place flight deck design. Of course, this achievement has also contributed to reducing the operating cost of aircraft.

2.12.4 Electronic flight information systems

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This system is at the 'heart' of the new airliners. An electronic flight information system (EFIS) nowadays comprises liquid crystal displays (LCDs) on which primary flight, navigation and systems data are shown to the crew. There are usually two display screens per crew member and they take over from the mechanical attitude director and horizontal situation instruments (ADI and HSI). They do much more than simply present the original instrument data in electronic form and have become

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known as primary flight display and navigation display (PFD and ND) respectively. Compared to their predecessor instruments, these are superior displays in respect of reliability and legibility. Circular needle-based pointer instruments have been consigned to history, although it is interesting that many of the display characteristics of old instruments are retained on electronic displays, because the human eye has a strong affinity to 'pattern recognition' and in the subconscious the human mind will 'read' the rate of change of a variable from the motion of a dial-mounted needle. The flight deck changes were often achieved with little need for well-practiced crews to learn new ways of assimilating information and in that regard the potential impact of change on safety performance was minimized.

2.12.5 Flight management system

This was the third of the three highly integrated systems that first saw the light of day around 1982. A flight management system (FMS) is a computer on board the aircraft that, in addition to incorporating all the 'software' of the PMS, has electronic memory that stores navigation aid and airport databases, the flight plan (in fact, many flight plans, of which the one of current interest only might be selected) and the airline's operating procedures.

When the crew is commencing a flight they declare departure and destination points (or a flight code), and the system will retrieve the flight plan. It will request or deduce aircraft data (such as payload and fuel load) and weather information, such as the wind forecast, and create a real-time flight plan that will forecast time en route, taking account of ground speed and air temperature variations, etc. The PMS-related core of the system will instruct the crew which level/speed combination will make for the best economic performance. It will also set up navigation and communication receiver sets, retuning the units as the flight proceeds, and so on. Throughout a flight it will be computing navigational data and presenting to the crew such information as time to go, distance to go, top of descent, etc.



The FMS can also be linked directly to the AFCS. On departure, when

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told to fly a certain route, the FMS will obey all the built-in characteristics of the procedures in terms of minimum/maximum speeds, altitude/level clearances at waypoints, etc., and can be used to steer the aircraft, fully automatically, from a point soon after take-off to the point where it is stationary at the end of the landing roll.

The FMS is a small unit, usually located just ahead of the throttles, one on either side of the centre console. On its face there is a complete alphanumerical keypad, a small number of dedicated 'function' keys and a six-line electronic display. It looks inconspicuous, but it is a vital piece of equipment.

The above were all 'integrated', in that they used common interfaces and were fully compatible when different suppliers were selected to supply different parts of the complete system for an aircraft. Figure 4.7 adds a pictorial aspect to this. Alongside them, stand-alone systems developed, and have proved their worth in many ways. These devices are dealt with next.

2.12.6 Ground proximity warning system

The ground proximity warning system (GPWS) was a microprocessor-based system, developed as soon as the technology was available (early 1970s) and tailored to assist a crew who had inadequate spatial awareness to appreciate that they were in a position that was perilous. In safety requirement terms itwas designed to recognize a set of circumstances that were potentially 'major' in terms of a safety effect and to provide the guidance necessary to alleviate the situation. The situation of concern was controlled flight into terrain (CFIT). The unit simply took radio altimeter data and barometric altimeter data from the appropriate data-bus lines (thus it was very easy to install) and detected unacceptable combinations of the height above terrain and the terrain closure rate, issuing a verbal 'whoop, whoop, pull up!' warning. The device would detect when an aircraft was descending close to terrain and even when an aircraft was level and the terrain was rising beneath the aircraft.

The primary terrain-protection 'modes' were soon supplemented with additional modes that monitored glide slope deviations – shouting 'glideslope, glideslope' – and even detected the rare, but potentially catastrophic, instance of when an aircraft would begin to descend after take-off, owing to circumstances such as retracting the flaps at a low speed, in which case the system call was 'don't sink!' After its introduction as a mandatory system in commercial aircraft in the late 1970s, the incidence of CFIT events reduced dramatically. It was claimed that it cost less than a new aircraft paint scheme and yet would save lives.

2.12.7 Enhanced ground proximity warning system

GPWS was not able to see 'ahead'; it was a device with efficiency limited by the fact that it used the radio altimeter, which looked downwards. As mass memory devices became available the GPWS was linked to an electronic elevation map, which became available because satellite-based radars had mapped the Earth's surface to a consistent level of accuracy throughout the 1970s and 1980s. The system could now detect if the terrain was above the aircraft, in the near region and whether the rising ground that was about to trigger a warning was in fact a terrain feature that would soon flatten off and not be an impediment to the aircraft's progress. This alleviated a lot of 'false warnings', which had plagued GPWS operations in very difficult terrain, and the new system became widely available in the 1990s.

In addition to producing a verbal warning the enhanced GPWS (EGPWS) could 'draw' terrain on the navigation display, so the crew could see the contours of nearby mountains as they descended into valleys. The visual reference was compelling and good, provided the software was reliable. As these

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notes are written the certification of 'synthetic vision' that takes this display technique a stage further is taking place.

2.12.8 Terrain awareness warning system

The terrain awareness warning system (TAWS) is a standard-fit item on the latest generations of airliners. In addition to providing a plan view of terrain (usually as contour patches that turn amber and red if minimum height criteria are breached), TAWS draws the terrain ahead of the aircraft (contributing to 'synthetic vision') and an illustration of the profile under the intended flight path, which is comparable with terrain drawings used on instrument approach charts. This needs FMS assistance and the display is integrated into the EFIS ND. This might be the final nail in the coffin of the voluminous loose-leaf flight guides that pilots have long had to carry and update periodically. The advent of an electronic library was heralded in the late 1990s and the fact that Boeing purchased outright one of the major suppliers of charts in later years almost cemented this development as a certainty. Expect safety regulators to crawl over the manual 'updating' procedures, cognizant that a failure to supply accurate data will be potentially catastrophic in electronic flight deck operations.

These were far-fetched ideas barely a decade ago. Aircrew flight bag manufacturers can expect demand for their product to diminish and 'posers' with such accessories should be aware that they will be 'old-fashioned' if they do not change their ways. For a decade or two it might be the biggest differentiator between the 'haves' and the 'have nots' of the flight deck community.

2.12.9 Traffic collision-avoidance system

As the world's airspace became more crowded there was one horrifying prospect, and that was the chance of a mid-air collision with another airliner. The possibility existed from the first day that two aircraft were airborne simultaneously and as traffic levels rose, sadly, the opportunity increased, and the record of such events rose too. Sometimes this took the form of an unequal encounter, with a light aircraft smashed by an airliner. While the dented airliner and its shaken occupants survived, the light aircraft occupants became aviation fatality statistics. However, this was not inevitably the case, as an airliner struck in a way that it suffers a catastrophic failure leads to huge loss of life. Airliner-on-airliner collisions were rare, but as high-accuracy navigation systems have become commonplace, the incident rate is increasing, and the outcome is most certainly related to the cause. Of course, the ATC system, through its separation criteria, should render such a possibility as acceptably small. The risk assessment of such cases is one thing, but the way that circumstances have conspired to create the 'loopholes' that accident analyses have revealed hasleft no one in the safety community in doubt that an on-board collision avoidance system is vital for future operations.

In fact, research in this field was underway over 30 years ago. Thoughts turned to putting radars on airliners, but it was impractical (because airborne radars – as used in military fighters – are heavy, expensive and not very reliable) and the field-of-view of a radar is limited. If the latter problem was addressed in the manner employed for airborne early warning (AEW) aircraft, the solution was more than one radar or a radar mounted within a rotating redone. The same impracticality was signaled. What did emerge was very novel and has proved to be very successful.

The traffic collision-avoidance system (TCAS) is a device that uses a low power ATC transponder interrogator on the aircraft to measure the distance and relative height of aircraft nearby. If it determines an unacceptable combination of range and range–range, and relative height, it will present an avoidance instruction on the aircraft instrumentation. The TCAS has been mandatory on almost all public transport use aircraft since the early 1990s. It employs a weak interrogator unit and a receiver that can assess responses from aircraft nearby (within 35 km or so). The actual range and the rate-of

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change of range (range rate) are measured, and from Mode C responses the aircraft relative heights are assessed. If the aircraft are vertically separated by at least 1000 ft and are not climbing or descending towards one another, their responses are ignored. Likewise, if the range rate is increasing (meaning the distance between the aircraft is increasing) the responses are ignored. In all other cases, if the range rate and range information suggest that the aircraft are within a 'trigger interval' (about 25 seconds), the TCAS will create a warning to the crews of both aircraft. The responses are coordinated to ensure one is told to pull up and the other to descend.

At first this system was frowned upon by air traffic control (ATC), whose natural reaction was to see it as a device that would question their own judgement with regard to separation criteria, but also because it seemed to put 'control' into the aircrew's hands. Aircrews, given the system added to their awareness of the traffic situation around them, were more enthusiastic. The TCAS started off as a unit with a dedicated display and then it became a display that combined the conflict resolution information with the vertical speed indicator (VSI). Nowadays, it is even possible to consider determining the precise location of other aircraft in the vicinity, whether they are a hazard or not, and to show them on the plan position layout of the EFIS ND. Most systems will do this adequately well, except that when an aircraft is maneuvering and thus changing its datum, this is not always an advisable way of using the system. ADS might be the 'integra table' sensor that will override that situation, however.

An unrelated development that has led to the TCAS being invaluable is that as aircraft have gained access to very accurate navigation data, thedegree to which they wander about a nominal course is much less than hitherto, and this excellent performance has the side-effect of meaning that two aircraft that are unmonitored, but following the same procedure, face the prospect of not just becoming 'too close' but of being guided towards a collision. The TCAS could not have emerged at a better time – and one reason it did is because some researchers had the foresight to see this rather doom-laden justification in their own assessments of emerging operational realities.

2.13 Future trends

The changes that have been charged in the operational environment have been continuous and the rate of change has not appeared to diminish over time. The advent of digital computers, in terms of the capability they bring to sifting, classifying and presenting information, is an area where the potential impact possibly has much further to run than can be surmised from a review of history and a simple extrapolation of current trends. The scientists and engineers are as sightless on these aspects as traffic forecasters working at the commercial end of the industry. In recent times the head-up display (HUD), which has graced high performance military cockpit coamings for 30 years or so, is likely to arrive on the commercial flight deck. This was not an apparent development even 10 years ago, because it seemed too expensive a device to justify. However, rapid development of new display technologies – much of it fueled by display-transmission expansion in public broadcasting – has triggered technologies that are working into aviation. The most important point to bear in mind is that changes arise for reasons. The causes are not always technology driven and with the way that the air transport system is beginning to evolve, with a wider sphere of concern of subjects including the covert impact of aviation on communities, it is almost inevitable that CNS and airliner systems of the future will be tailored to respect these wider perspectives. The challenge is to identify how these perspectives will emerge and what changes they will want. That challenge will be explored in later chapters.

UNIT-III

AIRCRAFT

Abstract: In this chapter the airliner manufacturing commercial and technical viewpoints are combined, within contexts that allow them to be interrelated. There is a systemic approach, starting with a view of each airliner as a project and outlining the lifecycle-related issues that influence commercial cost and risk. The latter is related to technical choices, which are assessed in terms of the options they deliver to a manufacturer. The influence of requirements, borne of the demand for services and the need to be efficient, plus the requirements that reflect customer expectations are grouped under an effectiveness heading, and are shown to influence a manufacturer's choices too.

Keywords: project cash-flow, infrastructure compatibility, aircraft operating costs, aircraft performance, customer service requirements.

Introduction

Aircraft are the most recognizable element of the air transport system. They are iconic within society and are, above all, the root of the solutions to any of the industry's pollution' problems. The understanding needed of airliners is of their value in commercial and service terms. There is no easy way of changing the course along which aviation technology is orientated. It can be deflected, but not changed abruptly, without grave economic consequences – on society, not just the air transport business. However, the manufacturers in turn are increasingly aware of how their products connect the natural and operational environments to the needs of the air transport system and the desires of society, both in the short term and the long term. Given that perfection is a witless aim, they seem sure to have a hard time at the hands of demands, which are influencing aviation through ideas of environmental '(flora and fauna perspectives implied) regulation. These horizons can be studied when the relationships that shape the industry have been portrayed.

Some 22 000 turbine-powered airliners are in service worldwide. The number has grown at a relatively steady annual rate for many decades, and this trend is fueled by passenger service demand that shows no signs of abating. In a typical year some 1000 new airliners will roll off the world 's production lines. They will be used for about 20–25 years, by which time they are usually retired and scrapped. Airliners are worked hard and a well-rehearsed motto is that, during its working life, an aircraft on the ground is an aircraft not earning money.

Costs:

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Aircraft are considerably more expensive in terms of cost per unit of mass than simpler items. For example, an airliner will cost between 800 and 400 US\$/kg (note that all prices will be quoted in US dollars). Generally, the smaller the aircraft, the higher the cost per kg. (This is an evaluation based on the maximum permissible mass for operations.) Some example prices are quoted later in this chapter, in Table 5.2. As an example of how expensive an airliner is, if a family car that took to the road at 1.5 tone maximum and was sold at an equivalent scale it would cost in the order of \$750 000. Banks and finance companies or, occasionally, airlines themselves finance the purchase of aircraft, and they must expect an aircraft 's capital cost to be recovered during its operational life. As well as seeking to recover this initial cost, it has to be borne in mind that running and servicing an airliner incurs additional costs. Even a relatively small (150–200 seat) airliner can cost \$50 million, and the largest of all reach the dizzy heights of a quarter of a billion (250 million) dollars. Look at an Airbus A380 and one is looking at a business that will need to generate about \$2.5 to 3 million per week. The Boeing 747, which has already graced the skies for almost 40 years, is not far behind. These simplified

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examples illustrate that, within airlines, each airliner is often a respectable-sized business. To begin understanding the modern airliner, it is important to consider the process through which it is created and what is involved, as this will also show why a manufacturer has to carry a commitment that they will be forecasting to fulfil needs for many years into the future. Their decision-making procedures do not allow them to change course very readily.

Project cash-flow:

Those manufacturers who have tried to break the mould about the variables involved inevitably have been ruled out of the business. Boeing continues a long-standing name, but on the way has subsumed Douglas, and at times has owned and operated other companies that it has sold on again. Airbus in Europe evolved from a consortium of European manufacturers. Between them these two firms account for almost all airliner production in the 150-seat and above category, throughout the world. The Soviet Union seeded a small and in industrial terms an inefficient industry, and there are signs that one day soon its legacy might re-emerge, but it has been in Brazil and Canada where small airliner production, the so-called regional jets, has been handled successfully. There are signs that there will be an Asian challenger, perhaps in the Boeing and Airbus sector, that will emerge from China or India. Consider what is involved, financially, in a modern airliner development and production programmer. The A380 has been quoted to be a \$10 billion investment by Airbus Industry, and the company's commitment is reported to be much higher by some independent sources. In other words, Airbus has had to invest a vast sum to cover the cost of designing the aircraft, create facilities for its production, nurture numerous support roles (both technical and commercial/administrative), certificate it and to maintain a steady rate of production. If each aircraft costs, in round figures, \$250 million per example, a simple comparison of the cost to create with the cost to customer might suggest that only 40 aircraft would generate enough revenue to recover costs.

The true figure almost certainly will be in the order of 250 aircraft, or \$62.5 billion worth of production, before all attributable financial liabilities are paid off. Airbus suggest that the production rate will be around 4 aircraft per month, or 48 per year, so the production line will have to run, at its best capacity, for at least 5 years. However, before production deliveries can commence there is the full design and certification programmer. Designing an airliner from project launch (and thus ignoring the cost of a lot of pre- launch research and development work) to when the first components can be fabricated is usually a number of years. Then there is a period when design and build activities overlap, leading up to the aircraft roll-out. In this period many of the facilities that will support production are built from scratch and novel processing techniques are tested, so development is often an on-going part of the job. After the first aircraft is rolled out '(more significant to the press than to the engineers) the aircraft will be tested on the ground. Eventually it will make its first flight, and then it and further examples will embark on a flight test programmer. The flight-test phase is usually 15–18 months and can require 5 or 6 aircraft – or fewer if it is a derivative 'rather than a new 'design.

Usually one complete aircraft structure is built and instrumented in a test rig on the ground, and although it will never fly itself, this test specimen will be the testing ground where aircraft longevity and structural safety issues are tested and have to be proved. Only after the landmark of certification, which follows successful ground testing and demonstration of performance, can deliveries commence to customers, and this will thus be Estimated current aircraft programmer costs (Source: evaluations based on published data)

Project	Production rate (aircraft/year)	Maximum cash-flow (\$ millions)	Break-even period (years)
EMB-170	48-72	1600-2000	16.5-17.5
Boeing 787-9	48-72	7500-10000	16.5-17.5
Airbus A380	48	15000	16.5-17.5

some 6 to 7 years after the project launch date. production effort can already be intense, but the rate at which units appear is initially sedate, as the supplier chain gears up and the production workforce in the manufacturer and supplier workplaces progress along what is often called the learning curve'. That critical 48 aircraft per year production rate is illusive, with perhaps 100 aircraft delivered in the first 3 years and the full complement of 250 achieved over a 6- or 7-year period. This will be 14 or 1 years after the project was started, and the time involved is called the breakeven period, for by the end date cumulative revenue (nominally now \$62.5 billion for a program such as the A380) will equal the costs to date. Clearly, that \$10 billion investment requires a lot of further confidence, financially and technically, to get to the point where the program is a business success for the manufacturer.

A cash-flow plot for a typical project will have a shape and a timescale like that shown in Fig.

On the diagram the maximum cash-flow value and the break-even period are annotated. The data shown in Table 5.1 are illustrative. The range in cash-flow values is based on assuming different levels of subcontractor liability, or cost sharing.

There are many hidden factors; perhaps subsidies that are unacknowledged and pay rates from country to country can influence the costs greatly. In Brazil, where the EMB-170 has been developed, the labor costs are considerably less than in the USA or Europe, but the company relies on subcontractors that do face US and European costs, so while the illustrative estimates are good for comparison they may be wide of the real data.





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All aircraft manufacturers face the dilemmas of trying to be lean 'with their costs and having to bite off a higher level of technology as each new project comes up for funding. As Airbus proceeded with development of the A380 in Europe, Boeing, the leading US aircraft builder, decided to avoid a head-to-head with a new large airliner and took an alternative route, investing in a smaller but even higher-technology aircraft. Eschewing big is beautiful', Boeing set out to break the mould by using far greater proportions of carbon-fibre material (much lighter than traditional metals) and a not inconsiderable number of less obvious significant new technologies, in a bid to get a design that is a smaller (this is relative as it is still a 300-seat plus airliner) yet as economical to operate and (according to their estimations) more flexible alternative to the A380.

The actions of these two manufacturing teams have set the stage for one of the most significant tests of commonly held wisdom in the history of the modern airliner. Boeing will not get much change from a similar investment to Airbus, but their aircraft, compared to the A380, will be barely one -half the mass. They claim that because of the higher-technology content in its design, it should be as economical – in terms of seat-km per unit of fuel used and can show that it is able to deliver this performance from smaller airports, and to do that even if they are relatively close or almost on the opposite side of the world. Aptly, Boeing have chosen to name their airliner Dream liner, and the prosaic family titled Boeing 787 should become commonplace in the future. It has been acknowledged that manufacturers are shy about revealing the true costs of their projects, but if the timescale suggested above is used as a basis and the educated guesstimates that contribute to the data presented at Table 5.1 are based on reasonable foundations, the sure indication is that each of these projects has locked a large part of each firm's resources to a project that will not bear fruit until around the early 2020s. It is also expected that these projects will still be in production as 2040 approaches or passes by. There is no short-cut to quick-change in the aircraft building business.

The Brazilian Embraer EMB-170 has been used as an indicator, as it is a truly small 'airliner with about 70 seats. Embraer have already developed and begun to supply examples of derivative airliners, ranging up to 125 seats. There is a belief that small is beautiful ', largely stemming from analysis such as has been shown earlier in Chapter 1, where smaller aircraft offer more choice and easier access to less busy airports. There is also the possibility that smaller aircraft will bypass hubs and thus relieve congestion at hub airports. The Embraer (and Canadian Bombardier, which also has a 50–100 -seat range of regional airliners) products are vying for this regime, against the 120–190-seat Boeing 737 and Airbus A320 derivative aircraft. The Boeing 787-9 and Airbus A380 will be the equivalent contenders at the top end of the market, with the A380 vying to assist in improving efficiency at hubs and the B787 trying to open the way for more point-to-point services. These are visions borne of late 20th century analyses that will be crucial to the shape of air transport operations in 2030 and beyond.

Aircraft prices (April 2006) (Source: Airclaims)

Airbus	\$ millions	Boeing	\$ millions
A318-100	21.9-28.4	737-300	6.00-15.6
A319-100	18.9-34.9	737-800	28.75-42.75
A320-200	11.95-42.15	747-400	37.3-107.55
A330-200	57.4-88.7	757-200	7-28.55
A340-300	46.8-100.16	767-300ER	19.4-67.75
A340-500	89.9-115.4	777-200ER	85-112
A340-600	92.9-126.4	777-300ER	67.5-136.3

Aircraft price

The quoted prices for some leading aircraft types, at early 2006, are shown in Table 5.2. The range of data represents the price range for oldest and newest examples of each aircraft type, so where a type has been in production for many years the oldest aircraft, like used cars, are relatively much cheaper than new production examples. There are tales of aircraft being bought well below the published price, which buoys optimism, but the circumstances have to be understood. In order to get a good discount, as with any purchase transaction, cash is more valuable than a presentation of credential, but just as important is timing. A good time to approach an aircraft builder is at a time of economic uncertainty. Just as the monthly production rate is beginning to wilt the builder could be in a position to offer a cutprice deal in order to hold a steady production rate, with a steady workforce, and thus to be in a position to respond more quickly to an upturn in demand when the sales situation improves. This is only possible if the market place looks certain to assure sales of this type in the long term. In terms of an example of business in action, the manufacturer is actually forfeiting short-term profitability with a view to achieving financial viability in the long term. Manufacturers do not give aircraft away, but in such circumstances they are likely to return and do business with them again.

Of course, the customer has to get their timings as good again to obtain as favorable a deal a second time.

Compatibility with the operational infrastructure

The cost of operating an airliner, as experienced by the operator, is also dependent on issues that concern operational compatibility and the regulations that arise from safety legislation. An essential requirement for an airliner is that when it enters service it interacts with everything around it in a compatible manner. The first way of providing such confidence is building the aircraft to established airworthiness rules, and it is therefore typical for all airliners to be designed to attain US and European certification '. The standards they use are the Federal Airworthiness Requirements (FAR) in the USA and the Joint Airworthiness Requirements (JAR) in Europe. They are similar in terms of structure, but subtly different at the content level. The implications of this paper qualification 'in fact go very deep. The aircraft will have been designed according to well-defined design rules, and the design assumptions involved in its definition will have been monitored thoroughly so that the assured life'of the aircraft – hours or cycles – is a genuinely attainable target. A complete test specimen airframe will have been used to validate a lot of assumptions in this regard. Its systems and components, from engines to lightbulbs, will have been shown to be able to meet the needs demanded by risk assessments of failure cases. Stemming from these rather esoteric studies many operating principles will have evolved, which will be the basis of the safety management system (SMS) process content implied in the aircraft 's type of certificate of airworthiness'(COA).

Hence, as it leaves the factory every aircraft has a set of documentation associated with it that will support both design-case evaluations and in-service operations. An aircraft flight manual (AFM), for example, will present performance data that have been validated in the design and flight test, and checklists will express crew responsibilities as procedures that arise from the risk assessments that have accompanied design and operating assumptions. Likewise, technical documentation will define maintenance program needs that are justifiable against operating criteria. Each example of the aircraft type has an individual COA. It presents data confirming that the aircraft complies with the assumptions of the type of COA, quoting precise mass data, and so on. It is the responsibility of the aircraft owner (and that might be a leasing company, not an actual airline) to ensure that throughout its operational life the attributes of the aircraft remain within the specification and that all who work on it adhere to the procedures appropriate to maintaining a valid certificate of continuing airworthiness' or certificate of compliance'. Such requirements mean that only appropriately qualified personal can take decisions regarding the adherence of appropriate policies. There are no short-cuts, and aircraft can be grounded 'for lack of due care and attention to any operational procedures. The many onerous requirements for an aircraft engineer 's license ensure that they can perform such duties effectively. Achieving compliance 'within the operating regime is a matter that clearly is linked closely to the regulatory and technical environments, as already described. Another matter is equivalent compliance within the operating environment, which means that the communication, navigation and surveillance (CNS) system elements that are used throughout the world are a part of the aircraft. There are many ways of doing this. At the minimum level – simply the interface – the aircraft will have a prescribed number of sensors and receiver/transmitting devices. How the information from these units is conveyed to the flight deck and presented to the crew can define several other levels of compatibility. On a small aircraft that is using the same airspace as a commercial airliner – an air-taxi type perhaps – the systems might present information in what can be described as a very raw 'fashion. The airspeed indicator, altimeter and vertical-speed indicators might be simple pressure-sensitive devices that move a needle against a graduated background dial such that the desired quantity is shown in a suitable manner. On a large airliner, while the sensing devices might use the same principles as those on the air-taxi, the detected pressures might be converted to an electronic format in an air data computer (ADC), which will then transmit the data to the instruments or even to additional electronic units. One of these, on an EFIS-equipped airliner, will be the computer display unit (CDU), which will integrate the data into a TV screen style display and show the information on an electronic screen. Thus, the ubiquitous dials of old are not visible, at first sight, on a modern airliner 's flight deck. (The components of these systems are described in Chapter 4.) The technical regulation will have stepped in when design solutions were being developed within the aircraft development programme. In order to meet safety needs, there will be standby instruments, which might be old fashioned looking devices (or on the very latest aircraft are very modern low-power liquid crystal display (LCD) units), so that a crew does not depend on a sole instrument. Most airliners have three sets of primary flight instruments and there are two crew members who can each compare the information on any two sets, at any time. Should a fault occur they can detect and reason the failure through a _majority vote '. There is also nothing to stop the design engineers inserting sensors into the computers and for their warning system to generate indications of non-catastrophic failures, possibly to a maintenance panel only.

A further addition in aircraft that are electronically equipped is to take the opportunity to integrate the paraphernalia of modern systems (such as AFCS, FMS, etc., as described in Chapter 4) that allow two pilots to monitor, decide and control all necessary aspects of on-board system operations. No matter how well these systems operate, in terms of taking away the workload associated with the primary flying tasks within a typical operation, the aircrew have to remain situationaware '. One of the greatest challenges within the operational regime of such extensively automated 'aircraft is to implement operating regimes, ensuring that the desired safety level in operations remains high enough to keep accident rate statistics on the desired trend line, which is often a human–machine interface difficulty. The way it is addressed is through training regimes, which use techniques grouped under the title crew resource management '(CRM). Within the CRM concepts that are used widely today, the crews learn to be responsive to one another and to be aware of and in touch with others. This can apply to controllers in the air traffic control (ATC) system or even the cabin crew looking after affairs within the airliner's passenger cabin.

AIR TRANSPORTATION SYSTEM	ИS
Source from Air Transportation Systems b	y Mike Hirst

The operational processes described above, and the consequent equipment requirements have an impact on operating costs. The procedures put in place are designed to monitor how well aircraft are operated, and thereby to allow warnings of potential compliance failures to be flagged, rather than left to occur. These are enshrined in safety management system (SMS) concepts, which every airline employee whose job entails an operational aspect will have encountered and had to reconcile with their desire to, at times, break the rules. There can be no breaking of the rules. If such events are recognized in monitoring procedures, severe consequences are as good as assured. This policy militates against minimizing operating costs, but the aim is to balance the need to be adequately safe with the desire to be efficient. It is on this latter aspect that the next viewpoint on aircraft concentrates its gaze.

Direct and indirect operating costs

When the operation of an aircraft is portrayed in simple terms, it is usually expressed in terms of minimization of costs. This is to do with efficiency, in that the more efficiently an aircraft is used, the cheaper it will be to operate. Operating costs are divided into two regimes, direct and indirect costs, namely:

Utilization (h/year)	X_i	$X_{\rm d}$	Total
400	10.0	1.0	11
500	8.0	1.0	9
667	6.0	1.0	7
1000	4.0	1.0	5
2000	2.0	1.0	3
4000	1.0	1.0	2
8000	0.5	1.0	1.5

Relative direct and indirect operating costs per hour related to Utilization

Direct costs are those incurred at the time of flight. They will include crew salaries(factored to including training, etc.), fuel, on-condition maintenance, airport and air navigation service charges, and so on.

Indirect costs are those incurred as a matter of ownership. The aircraft value, or the repayment lease if it is not fully owned, will be recovered as an annual repayment cost. Likewise there will be hull insurance, charges attributable to airline functions (administration, ticketing and reservation, building leases), and so on.

In terms of using an aircraft efficiently, this works between two extremes. Buy an aircraft and never fly it and it costs nothing in direct terms (but there will still be indirect costs) and its operating cost is theoretically an infinite cost per unit of production. Buy an aircraft and fly it every hour of every day of the year and one gets $(24_{365}) = 8760$ hours per year from it. There will be a direct cost of Xd per hour and an indirect cost of Xi per hour, where direct costs are incurred at the time of use and it is usually acceptable to treat them as a constant per hour' cost. As indirect costs are associated with expenditure that must be recovered annually, as utilization increases this will be a diminishing _per

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	Source from Air Transportation Systems by Mike Hirst

hour' cost. If the direct cost is treated as a constant and the indirect cost is expressed as a proportional quantity based on hours flown, the total operating cost is the sum of these. The relative values are as shown in Table 5.3.

The utilization value shown is based on the assumption (reasonable but not assured) that at 2000 h/year the indirect costs are twice those of the direct costs. If the aircraft was worked much harder – twice the utilization – the simplest assessment is that the total operating cost will fall from 3 to 2 units per hour. If an operator uses the aircraft less frequently, and for as little as 400 h/year, the operating costs rise to 11 units per hour. Thus the costs are well on their way to being infinite 'at zero hours of utilization.



Relative total hourly operating costs.

Note that once 8760 hours have been reached, the other extreme limit is reached, and at this point the relative operating cost value is 1.228. Figure 5.2 shows how the total hourly operating cost can be expressed, in such a theoretical assessment, against utilization. In reality, there are additional costs associated with very high utilization values, and the total hourly operating cost does not necessarily follow such a gentle curve. It tends to rise at high levels of utilization. In terms of costs, an airline striving for efficiency will try to fly each aircraft for as many hours as possible, per year. They will know that to exceed the equivalent of perhaps 16 hours per day for a long-haul aircraft and only 10–12 hours per day for a short-haul aircraft will bring little operating cost benefit, given that there will be operational constraints that will affect the service quality, an issue that will be addressed in the next section of the current chapter. Examples of service quality attributes are delays that accumulate, leading to reduced dispatch reliability, and the effects of curfews that occur at different relative times across time zones.

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	Source from Air Transportation Systems by Mike Hirst	
The way that the operating cost is expressed is usually derived from a process that takes account of the major influences and results in seat- km cost by applying a process that is illustrated diagrammatically in Fig. 5.3. The components of such an assessment are influenced by utilisation, seats per aircraft and aircraft repayment agreements, and as these vary from airline to airline it means that any assessment of operating costs is always a _ball-park' figure. The variations over a number of operators can be considerable. Some example operating costs, shown in Table 5.4, are based on data from late 2005 filed by US operators of Boeing 747-400 and 777- 200; they show how different the data can be. The filed data have been used



Components of aircraft operating costs.

to evaluate the \$/seat and \$/seat-km operating costs for a nominal flight in each case, based on an 8-hour operation covering 6500 km. It is always desirable to be able to express the operating cost of an airliner with reasonable confidence, such as being able to say that a new airliner is 15% better than an older type. The caveat is _under the same operating circumstances'. Hence, it is important not to read too much into actual operating costs. At first sight, the B747-400 data suggest that Northwest operations are much more expensive than those at United. Closer inspection shows that indirect costs are almost double in Northwest, which perhaps indicates a younger fleet or even a smaller fleet (without the economies of scale). There is a similar difference in the B777-200 data, with Continental

Typical airc	raft op	erating c	costs (Sour	ce: US	Form	41 r	eports, 2005)
	Direct (\$/h)	Indirect (\$/month)	Utilisation (h/day)	Assumed seats	Flight cost (\$)	\$/seat cost	\$/seat-km cost
747-400							
United	8697	298916	12.1	400	76863.7	190.41	0.029
Northwest	9155	588846	12.6	400	85 507.6	213.77	0.033
777-200							
United	6568	95618	12.0	330	54672.8	165.67	0.026
Continenta	6283	424 875	14.7	330	57971.5	175.67	0.027

having the greater indirect operating cost. If this is because of a younger and more reliable fleet, this could account for why the airline also achieves 20% more utilisation per day. In this case the \$/seat cost, which will be the yield target when airline operations are addressed in the next chapter, is thus almost the same on both airlines.

Balancing efficiency and effectiveness

Mention has been made of balancing efficiency with service quality attributes. Some of the service quality attributes arise from design and some from the way the aircraft is operated. These two roles will be discussed in conjunction, because it is the way that an airline uses the flexibility'that the designer offers that determines much about service qualities. The designers are responsible for the actual efficiency. This is addressed, in a traditional design process, by consulting with users on their operational requirements. The actual requirement for an airliner can be a very detailed document. Some stated needs will be very detailed, but the principal requirements that will affect efficiency and effectiveness are far from numerous and for general analysis they can be expressed in terms of four main issues.

These are:

- payload range
- operating speed (and altitude)
- maximum allowable field length
- performance target operating cost

The design team has to hold a common mental model 'of how the issues they address will affect the aircraft design. This process is engineering based and built upon an understanding of the four principal forces that affect an aircraft lift, drag, thrust and mass - as well as being able to attribute the relationships that link them through these four properties of the design

.Payload-range

Payload is the fee-paying load that can be carried between the origin and destinations, excluding any fuel remaining on landing. Most aircraft are designed to trade payload and range, such that the maximum payload can be carried only a proportion of the maximum distance over which the aircraft will fly with a reduced payload, which might approximate to the maximum passenger load. Essentially, the design is limited by the design maximum take-off weight (MTOW), themaximumpayload and the maximum fuel load. Because it is a statutory requirement, the MTOW

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	Source from Air Transportation Systems by Mike Hirst		

can never be exceeded in operations. The other two mass values are interchangeable. A _constant' in all of this is the operational empty weight



Aircraft masses and the associated payload-range diagram.

(OEW), being the weight of the aircraft prepared for service, but without passengers or fuel on board. The principle whereby fuel and payload can be interchanged, and how this translates into a payload–range diagram, is shown in Fig. 5.4. Provisional data for the Boeing 777-200LR (where LR means long range) provide an example. The aircraft weights (taken from a generic Boeing specification – there are differences in service) are:

OEW	145 149 kg (320 000 lb)
MTOW	347 814 kg (766 800 lb)
Maximum payload	63 956 kg (141 000 lb)
Maximum fuel	145 541 kg(320 863 lb)

The aircraft is, nominally, a 300-seat design, and at 100 kg per passenger (including baggage) the typical full passenger payload will be 30 000 kg. The design has been configured to carry as much payload again, meaning that, potentially, it will accommodate considerable freight as well as passengers up to a certain range.

There are four notable points on the payload range diagram:

- 1. Zero range payload (this is the maximum payload).
- 2. Maximum payload-range (the greatest range that the maximum payload can be carried).
- 3. Maximum range–payload (the maximum range with a maximum fuel load and taking off at the maximum take-off weight.
- 4. Ferry range, the furthest that the aircraft can fly with no passengers. The second and third points are the most significant on the payload–range

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	Source from Air Transportation Systems by Mike Hirst	



Payload-range diagram (Boeing 777-200LR) (Source: Boeing).

diagram, shown in Fig. 5.5, which is the actual payload–range chart for the Boeing 777-200LR. They can be seen to be where the limits of payload and range performance exist. The sloped portion of the plot between the second and third points represents the aircraft's payload–range capability when it takes off at the MTOW. These are the critical design conditions that eventually show up as an efficiency and effectiveness trade-off. If circumstances do not permit an MTOW operation (due to departure airport runway length, local air temperature or elevation limitations, which are issues addressed in more detail later in Chapter 7) the aircraft will attain any payload–range combination up to a line that is displaced to the left on the plot. The sloping lines on the example plot are spaced 11 343 kg (25 000 lb) apart.

When striving to meet a particular payload-range objective, the designer has to be careful that the requirement does not prove to be a target that requires so much out of the design that the performance is compromised with regard to operating costs. The design in this case will carry 300 passengers about 9700 nautical miles; to put that in perspective, the aircraft (the 777 LR variant) will reach most major US cities from Singapore. It is a performance that has been attainable in only the most recent (post-1995) era of airliners.

Fuel efficiency

The conversion of this performance to a measure of fuel efficiency requires prior knowledge of what operating conditions have been assumed. In the majority of payload-range assessments the aircraft is

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assumed to cruise in still air and to carry a nominal reserve of fuel. Assuming the reserve is 8000 kg for the 777-200LR, there are two points where fuel usage can be evaluated. These are Maximum payload–range (63 956 kg–7500 nautical miles (13 900 km)):

fuel used	131 616 kg
Maximum range–payload	(41 164 kg-9700 nautical miles (17 980 km)):
fuel used	156 408 kg

These translate into per kg fuel burn figures of Maximum payload–range 6754 kg-km per kg of fuel Maximum range–payload 4732 kg-km per kg of fuel Most airliners operate typically with 75% of attainable payload, so these figures diminish to around 5060–3550 kg-km per kg of fuel in normal service.

Compare this to a car that achieves 50 miles per gallon (in the UK this is 80 km from 2.55 kg of fuel) and can convey four 80 kg people (320 kg payload), which has an equivalent per kg fuel burn figure of 10093 kg-km per kg of fuel This car, with reduced occupancy, attains

- 3 occupants7570 kg-km per kg of fuel2 occupants5040 kg-km per kg of fuel
- 1 occupant 2520 kg-km per kg of fuel

These data show how relatively fuel-efficient a modern airliner can be. The actual fuel efficiency has improved steadily over gas-turbine airliner evolution. In terms of a benchmark, the equivalent full-payload use fuel data for the 707-320C of the mid-1960s was approximately one-half of the values quoted for the 777-200LR. This fuel efficiency figure has been chosen as a benchmark because it is the kind of criterion on which civil aviation will have to hang its reputation in the increasingly environmentally enlightened age. It is difficult to evaluate precisely; the spread between the extremes shown is about 0.7:1 for the 777- 200LR and it was in excess of 1:3 for the older 707-320C when equivalent data were evaluated. Even then, aircraft are not used to their full capability, which is also true of most surface transportation systems, so the full-capacity data are perhaps the fairest comparison to cite, and in such light the airliner fares well. Within the context of future operations, the current level of capability has to be improved. The way it will be done is two-fold: first, through detailed attention to technology and design that will enhance the vehicle performance and, second, through improvements in the way that aircraft are operated. The latter aspect will become a greater part of the considerations in associated chapters on airlines, airports and airspace.

Technical contribution to performance

Air-vehicle performance is technology-based, and as technology evolves so performance is improved. This links to a gradual change in airliner design criteria, and while aircraft configuration has been relatively static, the shape of airliners has changed subtly in recent decades. It could change remarkably over coming years as new performance demands are made by customers. A new structural material having the most influence is carbon-fiber reinforced plastic (CFRP). The Airbus A380 uses some all-CFRP components and has a large proportion of the fuselage manufactured using a unique aluminum/reinforced-plastic sandwich (trade name Glare '), while the newer Boeing 787 Dreamliner and its even newer Airbus equivalent aircraft, the A350, will use carbon- fiber extensively. The Boeing design is in a more advanced state of development and is anticipated to have an almost all-CFRPfuselage shell and CFRP wings. Airbus A350 plans are based on a similar technological basis.

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	Source from Air Transportation Systems by Mike Hirst

CFRP offers durability and is relatively light. The designers have to exploit the potential weight saving with care. For the 787 Dreamliner Boeing has allied airline requests for fuel efficiency improvements with a desire stemming from other areas of concern in the airports and airspace environments to offer more flexibility in operations. This is an early indication of the needs of the air transport system taking a part in the debates that range outside their direct area of interest. Boeing believe that the 787 will offer better fuel efficiency over a wide combination of payload and range values, and they also believe that being a smaller aircraft than most current long-haul types it will offer the opportunity for more point -to-point operations. The analysis of route networks in Chapter 1 has shown that airline hobbling is often the reason that some airports become congested, while others see their direct-route possibilities diminished. The 787 is being marketed as an aircraft capable of making hubs a thing of the past and opening more direct routes. The converse solution is to offer more capacity per movement at hubs, which is where the 600–800-seat A380 will be exploited. The reality will be, surely, that both types will make their mark.

Where the 787 is particularly significant is that the design is using the new technology adroitly. The aircraft wing is very flexible and in its detail, it is indicative of a push to achieve a higher aerodynamic efficiency (a higher lift to- drag ratio). This will reduce fuel-burn and will be improved by using engines that are achieving better fuel-burn performance than earlier generation engines. The combination of aerodynamic and propulsion system improvements should set a new benchmark, and on preliminary performance data released by Boeing (at September 2005), the fuel efficiency at the maximum payload-range point was shown to be 33% improved on the 777-200LR. There is probably some optimism in this figure. This has been achieved in one generation (there was an interval of about 15 years between the launch of 777 and 787 as projects) and exemplifies not just commitment by the manufacturers and their major suppliers to achieving significant environmental improvement but also in exploiting technology. In so doing, they do not minimize the cash -flow on their programmes and the risks they take are considerable. Most major companies involved in airliner design and suppliers such as aero engine companies all delicately tread the lines that delineate technical and financial risk. Aircraft efficiency is measurable in many ways. Some tabulated data regarding leading features of some significant aircraft types that have been introduced over the last 40 years are presented in Table 5.5 to exemplify briefly how some intuitive, and sometimes counter-intuitive, developments have taken place. Behind each of the strides that has been made in the evolutionary tale there is always also a tale of risk management on a grand scale.

Fuel fraction is a measure of the maximum fuel load as a proportion of the maximum take-off weight and is often quoted as a measure of technical efficiency. In the course of their life, short-medium-haul aircraft tend to complete more flights than long-haul aircraft and are more robust in terms of their construction. The consequence is that the fuel fraction is always lower than that of long-haul aircraft. (The differentiation is not so clear-cut, and the Boeing 757-200 and 767-400 are aircraft capable of trans- Atlantic operations and their fuel fraction is noticeably higher than other aircraft in their category.) Listing the selected types in date order emphasizes the fact that fuel fraction is not tending to rise, although it was expected that it would as lighter-weight structural materials became available. The observation is that as more fuel-efficient engines have been developed, the necessary range performance has been attained with smaller and less heavy aircraft. The tendency for the key aerodynamic efficiency indicator, the wing aspect ratio, to rise with time is evident, albeit the rate of increase is slow. There are always exceptions to the rule. The A380 has a relatively low aspect ratio, which is attributable to the need to provide a given wing area but to fit into an apron stand footprint 'that is 80 meters square. Hence aerodynamic efficiency has been compromised in order to make the aircraft compatible with modern airports. Fuel fraction and wing aspect ratio (span2/area) for different aircraft types (bold typeface shows short–medium-haul aircraft) (Sources: various)

Date of first flight	Туре	MTOW (kg)	Maximum fuel (kg)	Wing area (m ²)	Wing span (m)	Fuel fraction	Wing aspect ratio
Aug 59	Boeing 707-320	151500	72 503	283.0	44.42	0.479	6.97
Nov 59	Boeing 720	106 500	48 903	234.2	39.88	0.460	6.79
Apr 67	Boeing 737-200	52610	14 520	91.1	28.35	0.276	8.82
Oct 72	Airbus A300-B4	165 000	46 654	260.0	44.84	0.283	7.73
Sep 81	Boeing 767-200	142882	50 753	283.3	47.57	0.355	7.99
Feb 82	Boeing 757-200	115650	34 260	185.3	38.05	0.396	7.96
Apr 82	Airbus A310-300	123000	59 637	219.9	45.89	0.485	9.62
Feb 87	Airbus A320-200	77 000	19 959	122.6	34.09	0.259	9.48
Apr 88	Boeing 747-400	396 894	174 093	541.2	64.44	0.439	7.67
Jun 94	Boeing 777-200	286900	137 460	427.8	60.93	0.479	6.68
Aug 97	Airbus A330-200	233 000	112 067	363.1	60.30	0.481	10.01
Oct 99	Boeing 767-400	209 111	73 363	290.7	51.92	0.351	9.63
Aug 00	Boeing 737-900	79016	20 894	122.6	34.09	0.264	9.48
Mar 01	Airbus A340-600	368 000	156 487	437.0	63.70	0.425	9.26
Apr 05	Airbus A380	560 000	253 175	845.0	79.80	0.452	7.53
2008/9	Boeing 787-9	230 652	100 127	c.360.0	60.1	0.434	10.03

Operating speed and altitude

The cruising speed of all jet airliners is about Mach 0.7 to 0.9 (410 to 527 knots TAS), with most concentrated in the lower half of this band. Some designers have attempted to offer speeds between 0.82 and 0.88, but the aerodynamic performance is affected by increasing wave drag', which is attributable to the development of the supersonic shock wave that occurs at the speed of sound. To penetrate this region the wing has either to have increased sweepback or reduced thickness, and the trade- off with other performance attributes has never been acceptable. Technology developments could change that, but for the time being the short- haul airliners tend to cruise between 410 and 450 knots and have modestly swept and relatively thick wings that offer best field performance and good climb efficiency, while longer-range airliners have more swept-back wings and pay a price in terms of runway length requirement on take-off and landing, and cruise between 450 and 500 knots, with 480 knots being a very typical long-range economical cruise speed. These speed targets are achieved at between 30 000 and 45 000 ft. The shorter-haul aircraft use the lower altitudes, rarely climbing above 36 000 ft, whereas long-haul aircraft will use the higher altitudes. The latter is subject to aircraft mass, for on a very long-range flight the aircraft will be so much heavier at the commencement of cruise that it might not be able to climb above about 32 000 ft. For best performance aircraft should conduct a cruise-climb, with the aircraft steadily increasing its cruise altitude while maintaining a constant speed as fuel is burned and mass reduces. This does not tend to happen, as airspace service providers require that aircraft stay at a designated cruise altitude. They do allow a long- haul flight to climb in steps throughout the cruise phase. This is not as efficient as cruise-climb and is a topic on which there will be more to say in the later chapters.

Aircraft field length performance

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Consideration of cruise performance has intimated a trade-off with field performance, but there is much more to this. The larger the wing, the slower the take-off and landing speeds, and thus the less length of runway is needed to accelerate on take-off and to decelerate on landing. The actual area that will be needed, compared to the area needed for best fuel efficiency in cruise, is huge, and the palliative that overcomes this dilemma is the aerodynamic flap on the wing trailing-edgeandslats on the leading-edge. As flaps and slats are extended, they increase the degree of curvature in the cross-section, the so-called wing camber, and allow a given lift force to be generated at a lower speed. The flaps create drag, so they are used sparingly on take-off (when a small flap extension will bring considerable lift benefit without as much drag increase as with larger flap extensions), but on landing the extra drag is tolerable because the aircraft is lighter. The extra drag both reduces speed sensitivity and helps to improve the descent angle, making it easier to reach a designated aiming point on the runway. Flaps are a nuisance as they are complex devices that add mass and increase the maintenance burden. Many types of flap configuration have been used as designers have sought to trade-off mass and cost implications in an equitable fashion.

The considerations introduced so far have shown that take-off is critical in terms of being able to takeoff within an acceptable runway length. Safety regulation plays a large part in determining what will be acceptable overall, and the most significant failure case to consider – and the one that all pilots train to face, but hope that they will never do so – is the loss of an engine at take-off. Aircrew does not work in distances. They use what is readable on their instruments and what is critical to aspects of performance, chief among which is speed. A safety requirement is that in operation the aircraft should be able to accelerate to a certain speed, with all engines running, and that should an engine fail at this speed the crew should have enough runway ahead of them to execute either a take- off (with an engine failed) or to stop (assuming they will have brakes only). This is the take-off safety speed (called veeone', presented as V1). The handling pilot will be _heads-up'and watching the runway and the supporting pilot will be heads-down'monitoring speed. The supporting pilot calls V1 when the computed speed has been reached, and it is at that point that they know the take-off can no longer be abandoned without running out of runway length. The three major conditions that determine the safety speed are aircraft mass (or weight), airfield elevation (or altitude) and air temperature, and these are used to form the acronym WAT. Figure 5.6 shows the take- off field length performance of the Boeing 777-200LR for ISA standard day temperature. In order to assess other temperatures, further charts would need to be consulted and a take-off field length determined by interpolation. A take-off field performance chart shows that the longer the runway, the greater the take- off weight that can be achieved, and hence the greater the payload-range capability of the type can be exploited. The higher the airfield elevation and the higher the air temperature, the more runway length is needed to achieve a given take-off mass. These issues will be re-visited in Chapter 7, where airports are considered.

Take-off performance chart (Boeing 777-200LR) (Source: Boeing)



Take-off performance chart (Boeing 777-200LR) (Source: Boeing)

Typical operating costs

The structure of operating costs and their dependence upon many operational variables has already been explored (Section 5.4). The actual cost on a flight will also be affected by such issues as the payload– range and runway length available. If the payload–range is limited, by either airport elevation, runway length or air temperature, the operating cost will be affected in some way. It is always important to gather as much information as possible about the proposed operation, right down to knowing whether freight will be a significant part of payload and what en route weather conditions (especially wind direction and speed) will be frequently encountered. The dependence on the variables outlined will remain the same, but there will be limitations imposed by operations that will sometimes militate significantly against achieving optimum performance. These are considered within the context of airline operations in the next chapter.

Effectiveness

In addition to being efficient, aircraft have a considerable impact on many issues that can be referred to under the _service quality'banner. If little regard is taken for the norm, the differences can have an effect on operations that range from irritating to catastrophic. Some indication of the way these are tailored alongside the efficiency and cost issues already explored is relevant here, with the objective of setting out, in addition, the way that an operator's wish-list for non-technical operational parameters can be related to the design. For example, the way that airport stand dimension requirements have been allowed to play such a great influence with regard to the A380

design (it has am span, against a requirement that it should not exceed 80 m) is an indication that not all technical matters are assessed and decisions made solely on technical efficiency criteria.

Wake-vortices

A significant operational consideration is that wings create a swirl around each wing tip, called a tip-vortex. This swirls inwards, causing a downwash 'behind the aircraft. Sometimes the swirling flow is turbulent and so energy laden that any aircraft entering this region of flow will face the possibility of being upset. This is called wake turbulence, and thus if the vortex strength is large enough to cause the upset 'of a following aircraft, the separation between it and any following aircraft as they approach a runway has to be increased. This can reduce the attainable runway capacity,



Span-loading: comparing categories of _heavy' jets.

thus affecting the total amount of traffic that can be handled in busy periods at an airport. A rough indication of the vortex strength is provided by the span-loading (mass per unit span). Based on MTOW, the span loading has been plotted as a bar chart in Fig. 5.7 and the most vortex-critical types are the darker bars.

Interestingly, the Boeing 757-200 has been classified as an aircraft that needs extra approach separation behind it, although it is not, on this assessment, significantly worse than smaller aircraft. A perplexing problem for the A380 design team has been ensuring that the vortex behind this very large aircraft does not upset following aircraft. The impact of this issue on airport runway capacity is considerable, and it has been important that Airbus show that their new aircraft will not require any substantial change in spacing between successive arrivals.

Cabin dimensions

An airliner 's fuselage is usually a tubular, streamlined, component that accommodates the crew and payload. It might also enclose fuel tanks and even have space devoted to stowage of the landing gear. There will be the flight deck, where the aircrew sits, the passenger cabin, with seats, galleys and toilets, baggage and freight hold, and small regions that are packed with electronic systems used to communicate or navigate the aircraft and perhaps to assist in its detection in surveillance systems. The most important design consideration is the selection of a cross section. As aircraft cruise high in the stratosphere, the air pressure within the passenger cabin must be much higher than it is in the atmosphere. To accommodate the pressure differential at typical cruise altitudes (it is about half the sea-level atmospheric pressure) makes designers prefer a circular, or near-circular, cross-section. An oval cross-section is desirable for multi-deck aircraft, so that the walls 'are reasonably close to being vertical, but the Boeing 747 experience has been that the structural loads can cause the oval shaped frames to crack sooner than circular frames, thus diminishing airframe life. Nevertheless, Airbus has adopted a very noticeably oval section for the A380, which has three decks - two for passengers and one for the baggage and many of the aircraft 's systems. Newer materials (in the case of the A380, an aluminum/carbon-fiber sandwich) offer the prospect of balancing the requirements of obtaining a lightweight design and a structure that has good fatigue-resistance. Boeing is using carbon-fiber fuselage sections for the first time on an airliner, on the 787 Dreamliner, and this promises the prospect of a less maintenance-intensive design solution, thus offering long-term operating cost savings.

on all airliners the passenger accommodation is invariably in rows of seats set a fixed distance apart (the seat pitch) and with seats in double or triple sets next to the windows. A small aircraft might have only three or four seats per row, and up to six seats if the cabin has just one aisle. These are narrow body airliners. Larger -diameter cabins have two aisles and a central set of seats. This is usually only justifiable (in that the wider a cabin, the more frontal area it has and the more drag it will generate) when it is able to accommodate eight or more seats in a row, with ten seats the maximum number used, in an approximately 6 m (about 20 ft) diameter cabin. The different cabin configurations that airlines use is discussed in the next chapter, when the seat pitch and other comfort factor issues are examined at the same time as user operational and business strategies. It is usual to have facilities galleys for food storage and distribution (very rarely for preparation) and toilets – fore and aft, with some mid-fuselage facilities on larger aircraft. All airliners have the passenger access doors on the left and galley or servicing doors on the right. The under-floor baggage access doors are also on the right, these being conventions that make aircraft compatible worldwide with air -bridge or air-jetty access facilities at airports. The ability to tailor seat configurations to meet different ratios of galley area per passenger, number of passengers per toilet, in-cabin baggage space per passenger, aisle width or total space per seat is not trivial for an airline that is trying to win the accolade of best airline' against their competitors. The airline that asks for a little more width is unlikely to be listened to for to redesign a fuselage is a multi-million (if not billion) dollar job and will take years. Sensible use of the available cross section is crucial to success, and this will be referred to again in Chapter 6.

The flight deck

The evolution of this part of airliners makes an interesting case study, not least because as systems have been made simpler to use, the crew size has diminished, and now almost all aircraft have a twoplace flight deck for the captain and first officer. In the 1950s the long -range airliner had two pilots, a flight engineer, a radio operator and a navigator. These three additional crew members still have a place on a few older aircraft, but everything on the drawing board since the mid-1970s has had a twoplace crew compartment. The systems that have wrought so much change need to be examined, to see where technology has been applied, almost invisibly, but on a massive scale, as the changes that have taken on historical connotations are liable to be overshadowed by as much change again in the future. Of the three crew members that have been automated out of existence, the flight engineer has been the most recent to go. In their day these crewmen nursed the aircraft's engines and monitored a myriad of systems, of which fuel, electrical and hydraulic systems were the most operationally important. They would also control air conditioning, perhaps responding to passenger requests fed to them via the cabin crew. Modern engines have built-in monitoring and electronic control systems, and can be relied upon to perform flights without human intervention, except when the crew respond to a hazardous mechanical failure. Knowing what represents the most significant failure conditions, engines are festooned with sensors that not only record health' but even store it and transmit it electronically to the aircraft's operational base. If an engine begins to misbehave, benignly, the crew are among the last people to be informed, and often become aware of concerns only when engine technicians await their arrival at the next airport. The systems that do this have already been described in Chapter 4 on the operational environment.

The manufacturer's overall remit

In terms of what they do, the foregoing sections have set out how the aircraft builder has two important in house 'objectives: first, to run a financially viable business and, second, to ensure that their product is compliant with the safety and operating rules set out by the operator's own regulatory authorities and the providers of airspace services in the regions of sky within which the aircraft will be used. Additionally there are technical objectives that must be addressed and result in an aircraft whose capabilities will meet user's expectations. In terms of how the user will see the product, the most important indicators (of a myriad of indicators of efficiency) are the payloadrange, operating speed and altitude, runway field length performance and operating cost data. Finally, the degree to which the aircraft is compatible with operator needs, from crewing levels to door locations, and the scope for innovation service initiatives, in what can otherwise be regarded as just a bland passenger-carrying tunnel, has been expressed as effectiveness objectives. Balancing these issues and respecting the changes and increased expectations of customers are what make the task of designing and manufacturing aircraft an exacting, albeit not always 100% scientific, endeavor. There is still room for some _individuality'to creep into airliner design, although if the constraints faced are not fully respected by designers, the most innovative solutions can be conspicuous failures. This chapter has briefly expressed how aircraft builders try to maintain a balance between financial, statutory, efficiency and effectiveness requirements that are as challenging as ever before. In this regard they do not stand alone, as a similar mix of needs faces the stakeholders in other contributors to the industry – airlines, airports and airspace service providers, for example. When all their needs have been qualified there is scope to consider whether the individual parties should keep their own objectives in mind, above all else, or whether there are more all-embracing objectives that can be recognized as emerging and that everyone needs to address.

UNIT-IV

AIRPORTS AND AIRLINES

Abstract: This chapter builds links between airports and the aircraft and airlines that they serve andthe airspace providers that serve them. It starts with forecasts and requirements that determine the scale and disposition of a site. Safety-related regulation effects are described, and the functions that accompany arrivals and departures, plus formalities in the terminal, are considered. While airlines strive to be different from each other, all airports are different, so describing them in compatible terms is revealed to require careful judgments. A set of four perspectives shared with the other elements is developed to assist in integrating viewpoints. Key words: airport master planning, site selection, aircraft–airport compatibility, runway, taxiway and apron and terminal configurations, capacity, demand and delay relationships.

Introduction:

While airlines strive to be different from each other, all airports are different. Their setting, scale and amenities set them apart from one another, and yet most airline strategists would happily force them to conform to so much uniformity (in the terminal at least) that if they ever got their own way, they would become a component of the system that would be hard to distinguish. In this chapter explanations are offered for their inevitable operational differences and insight is presented into what makes the operational and passenger amenities so different. Many of the world's main airports began as municipal amenities, with flying clubs and entrepreneurial airlines sharing facilities throughout, but nowadays almost all passenger-serving airports are businesses in their own right. Aerodromes that are used for public transport duties are licensed and managed to exacting standards. Such conditions are imposed with safety in mind and employ financial strategies that aim to ensure that the whole place is run as a business. An aerodrome that has regular commercial services provided by airlines is an airport, and it is these locations, some 2000 worldwide with a regular timetabled service, that are of interest in respect of the air transport system. There are 20 000 or more additional places where aircraft can alight and take-off again, and can range from enormous military airbases to farmer 's fields. They do require airspace, and in this regard their needs occasionally do conflict with those of the airport operators and users. This is a difficult issue, and the airspace needs of all aviators are addressed in the next chapter. For now, the desire is to explore what there is to know about airports to an extent that will be compatible with the way that aircraft and airlines have been analyzed already.

Setting up an airport

In all countries, an airport needs a licence. This will be issued by the local aviation regulatory body, whose requirements will be based upon the standards and recommended practices (SARPs) of Annex 14 to the ICAO Chicago Convention. To license an airport the licensee has to state where it is, provide physical details and in support of the latter will need to commission a geographical survey of the site and its environs. A managing team will need to be declared, and some staff, as has been seen to be the case with airlines, have to be named and deemed acceptable to the licensing authority. Essential components of a civil airport are one or more runways, associated taxiways and aprons, of sufficient size to accommodate demand, passenger and cargo-handling facilities, plus a local airspace control unit and rescue and fire-fighting services. The infrastructure, which will include lighting and radio aids, will need to be adequate to provide the service levels expected of the airport, in weather conditions down to the operating minima that the serving airlines agree with the airport operator.

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Additionally, it might have fuelling facilities (very few airports do not offer fuel), administration buildings, and so on. Selling a property is said to depend on _location, location and location ', and a similar phrase can express where best to locate an airport. A magnificent airport in the middle of nowhere is unlikely to be of any use to anyone. Building a massive airport beside a small township might also be reckless, although if that township is on an island and tourism is its main source of income, the airport might be the lifeline for the commercial prosperity of the township and the island overall. Usually large airports are near large cities or towns, but this is a simple rule that is applicable in only the majority of cases, not in all situations.

Most airports in the world have grown from humble roots and are therefore often not ideally located for modern operations. They might be conveniently located but have congested ground links and cause annoyance to nearby residents because of the noise they create. In some cases, new airports have been built on green field sites, but these are only justifiable when the traffic levels are high; in such cases the investment is often so great as to need municipal or national financial support.

Airport demand

The forecasting of demand for passenger and cargo services from an airport is not very different to that employed to analyse airline routes. The local demand will be considered first; the larger the population that can access the airport in reasonable time, the more likely it is that there will be a justification for a service to any location. An airport isochrone is shown in an earlier chapter (see Fig. 2.3). Local prosperity is an additional factor to include in such evaluations, with greater affluence in a society invariably leading to more demand for services, across business and leisurecategories.

Airports that are located in a convenient _hub' location will sometimes find that _transfer' passenger demand is considerable. Analysis of route structures has already shown that a centrally located airport in a homogeneously populated region will outperform all other airports, simply because it will be the place where airlines that are carrying passengers travelling to/from outlying locations will choose it as the place where their users change their flights. Finally, the status of a place, in terms of it being attractive to tourism, an international business centre, etc., will generate its own demand. The needs of the many user categories that have been recognised are often profoundly different, and airports cannot afford to ignore their different needs. This is what contributes to making airports such interesting entities to create and develop, for while business users might want lounges where they can relax and even work, leisure passengers might so strenuously desire shops, bars and restaurants or cafes that they will regard an airport as a pleasant experience even if the floor space is crowded. Where an airport develops a niche as a cargo centre the requirements will be very different; in some airports the ability to operate cargo at night and passenger operations in the day is seen as a good efficiency factor. However, extra night-time flying will not go unnoticed in the neighbouring communities, so the advantages come with strings attached.

Airport sitting

So far reference has been made solely to the airport being conveniently located. Where there in no historic precedent, a new airport will be located in close proximity, or with easy access assured, to population, and where meteorological records show that there are suitable weather and climatic conditions. Ideally, the site should allow the runway(s) to be aligned to the prevailing wind direction(s)be as obstacle-free as possible, especially with regard to runway centerline should not be prone to low clouds – airports perched on hills are susceptible not be prone to fog – river basins, where radiation fog often forms, are susceptible.^L

To decide which direction to align runways, it is important to remember that aircraft must take off and land into wind. It is therefore best to know if there is a prevailing wind direction and to design the airport around a runway, or runways, that will minimize the need for operations in a strong cross-wind, as such operations are less conducive to safety. Acceptable cross-wind limits are set by consideration of the extent to which a drift angle will develop. The higher an aircraft's approach speed, the more likely it is that it will have a higher cross-wind limit. Also, jet aircraft tend to have better controllability in cross -winds than propeller aircraft. The wind rose is a graphical presentation of the frequency of time that wind is experienced in different speed and direction combinations (and the frequency is usually expressed as a percentage probability in the diagram). A wind rose is best constructed from local weather information, and a preference would be to gather observations of wind direction and speed over a long period of time (at least one year). An example wind rose is shown in

Fig. 7.1.By drawing a line in the direction of a proposed runway, as shown in Fig. 7.1, and then adding parallel lines at a distance that is equal to the maximum cross-wind limit expected to be acceptable, the summation of probability values in the enclosed area reveals the percentage usability of the runway. (The crosswind value used will be related to criteria that aircraft operators declare in their aircraft flight manuals, which with modern jets can be around 30 knots). The wind rose thus presents an estimate of the percentage of time that a runway will be usable.

In modern designs the emphasis is on getting a single runway that will handle jet operations on an acceptable proportion of occasions. A recommendation is that the usability factor should exceed 95% of occasions. This can mean that a runway will be unusable on 18 or so days of each year, which is a considerable proportion, and it is the reason why many airports still retain a second, cross-wind ', runway. It is usually the case that crosswind limitations are more critical when landing than on take-off, and as landing distance requirements for aircraft are usually less than the required take- off length, the crosswind runway can be of reduced length. Runway numbers arise from the magnetic direction in which they are orientated; therefore 2408 is runway 24. If there are parallel runways, they



Wind rose.

have a suffix for left (L), right (R) or centre (C); hence 27R is the right hand of a parallel set orientated 2708 (in fact between 2658 and 2758) magnetic. Because it can be used in either direction a runway orientated 2408 will be at 608 in the opposite direction; this will be referred to as runway 06/24.

Runway characteristics

The runway is the most critical airport element, in that without it nothing else would suffice. It has numerous attributes of which paved length, obstacles and some of the physical aspects are considered here, with concentration then attached to runway capacity, or the ability of a runway to accommodate a given number of movements in a declared period. These attributes suffice to allow runway performance, with regard to how it interacts with other elements of the air transport system to be evaluated.

Runway length

Length can be such a critical requirement that direction is often compromised to accommodate an adequate length runway. The runway should be able to handle all the anticipated demand, so analysis of the





Requirements of the anticipated aircraft types and the services they will operate is an essential design task. This is not easy when an operational requirement based on a future scenario is being investigated, but since turbo-fan aircraft have become commonplace the correlation between runway length and range requirements has tended to stabilize, and even slip back a little, making shorter runway airports more competitive. The previous notes on aircraft have shown how take-off mass is related to payload and range requirements. The chart for the Boeing 777 -300 (Fig. 7.2) is a typical example of aircraft take-off performance. It shows how airport elevation is as significant as aircraft weight on the runway take-off length requirement. It must be stressed that air temperature also plays an important role, and separate charts relevant to different air temperatures need to be consulted to assess tropical locations. The interpretation of such charts deserves special consideration when

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operations are close to the aircraft's limits, as the availability of what might seem mere tens of meters in declared distances can sometimes have a profound impact on the commercial value of an operation. Runway declared distances

The runway paved length is not always the runway length that is used to assess operational capability. There are four specific runway length definitions, called declared distances. The definitions are as follows.

Take-off distance available

The take- off distance available (TODA) must exceed the take-off distance required (TODR) for each operation (TODR is the value considered in Fig. 7.2). The TODR is defined as: _With all engines operating this is the distance required to accelerate to rotation speed and achieve a scheduled screen speed at a height of 35 ft (10 m) plus 15% of the total. With an engine failure at V1 the distance is no factored by 15%'

Take-off runavailable

The take-off run available (TORA) must exceed the aircraft take-off run required (TORR) for each operation. The TORR is defined as: _With all engines running this is the distance required to unstick plus one third of the airborne distance between unstick and the screen height of 35 ft (10 m) plus 15% of the total. With an engine failure at V1 the requirement is similar but not factored by 15%.

Accelerate-stop distance available

The accelerate–stop distance available (ASDA) must exceed the accelerate– stop distance required (ASDR) for each operation. This is defined as: _The distance required to accelerate on all engines to V1, at which an engine failure is assumed, and then bring the aircraft to a halt.' Some authorities permit the use of thrust reversers in establishing this distance, but then add 10% to the stopping distance. Variations in such definitions exemplify how international regulatory guidance stops short of being 100% prescriptive, but forces a common orientation in the way that safety standards are applied

Landing distance available

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The landing distance available (LDA) is usually less of a constraint than take-off. However, a wet surface, especially slush, is a serious impediment to stopping. All licensed aerodromes will present the above four declared distances in their national aeronautical information publication (AIP). The subtle 1 V1 is the take-off safety speed. For the crew this is a vital defining point in the take- off process, with any event that is judged to have a bearing on the safety of an operation occurring before this speed triggering an aborted take-off. The most common quoted case is an engine failure. The evaluation of V1 will have ensured that, beyond this speed, in the circumstances present on the day, the crew will have the ability to become airborne and to climb safely. Variations between published lengths will alert a user to the presence of obstacles that have been taken into account in the derivation of the distances, and the obstacles will be listed. Note that the TODA can exceed the runway paved length (usually by a small amount, but it can be as great as 50% in specific cases). All other declared distances will be equal to or less than the runway paved length. Any aircraft using a runway that will need more runway length than is available to operate at its maximum take-off mass

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is obliged not to exceed the restricted (or regulated) take-off mass (RTOM). This is determined by entering the performance chart with the appropriate declared runway distance. (Aircrew are required to remain competent at using their aircraft flight manual graphs, but increasingly an airline will have a computer system with airport and aircraft performance databases that will perform this task for them.) Because of the safety factors 'included in the declared distances, when operating at the maximum permissible mass from a particular runway in normal operations an aircraft still becomes airborne long before it reaches the runway end. If a crew does abort at the V1 speed, the certification criteria should ensure that there is adequate runway length still available for the aircraft to come to a halt or to become airborne and to clear all obstacles, with one engine failed.

Aerodrome areas

Additionally, flat and clear areas around a runway are essential, for operations at an airport. These can be within the aerodrome boundary and beyond it.

Runway strip

The runway strip is a region around a runway, which should be relatively flat and unobstructed. It protects an aircraft and its occupants in the case of running off the runway and eliminates obstacles that might be hazards if the aircraft deviated from the runway centerline during a go-around. Small installations that are deemed essential to safe aircraft operations are allowed within the strip (e.g. lights and signs), but they must be frangible.

Runway end safety areas

Runway end safety areas (RESAs) are regions beyond the runway strip in which it is assumed an overrunning aircraft will come to rest. In recent years the desirable length has been increased from 90 to 240 m.

Obstacle safeguarding

Beyond the airport boundary, obstacles can be relevant at up to 20 km from an airport and their impact on airport operations can be considerable. The regulations here are fluid, however, and where there are significant and unmovable obstacles procedures can be developed that will require due diligence and be acceptable to regulators. The most obvious example in recent years was the Hong Kong Kai Tak airport, where aircraft flew an approach along an offset ILS and turned in the final stages of the approach while relatively low over a heavily built-up area of the city. This was acceptable while demand could be accommodated, and in the late 1990s a new airport was introduced about 20 km away that has allowed less hazardous procedures to be used.

Figure 7.3 shows the obstacle limitation surfaces (OLSs) that are defined for an airport runway (exaggerated, for the gradients are very shallow). The application of these criteria is sometimes referred to as _aerodrome safeguarding '. There is a degree of _common wisdom'in how these surfaces are described, but there are collision-risk models (CRMs) that can be used to substantiate risk. This kind of analytical process is used to justify procedures that pertain to airports in difficult locations. If there are obstacles beneath an approach, the extent to which the most significant example penetrates the obstacle surface will determine to what extent the surfaces are displaced '(towards the runway). An 8 m penetration



Airport obstacle planes.



Runway declared distances, with an obstacle (the TODA to the left might extend beyond the paved length – see notes). of a 2.5% slope will lead to an $8 \\ 100/2.54320$ m displaced threshold. This will create a region of the paved runway that is unusable for declared landing distance. However, it will still be usable when aircraft depart in the same direction. The way this kind of consideration affects declared distances is shown diagrammatically in Fig. 7.4.

Runway capacity

The likely number of arrival and departure movements per hour that a runway can accommodate is crucial to determining how busy an airport can be, either in its peak or, if it is a very capacity-constrained airport, continuously. There are several very precisely defined capacity definitions. Two are of interest in this text, which will be adequate to allow assessment of an airport 's traffic capability. Ultimate capacity is the maximum number of movements per hour that a runway can achieve. It is usually a theoretically determined figure, developed from a mathematical process that considers the mix of traffic, usually divided into four categories:

Heavy	all airliners that require wake-vortex 'separation
Medium	all jet airliners and business jets, and some large propeller types
Light	all propeller aircraft, excluding single-engine propeller types
Small	single engine, typical up to six-seat, general-aviation types

A representative runway occupancy time (ROT) for each category is determined and the separation standards used at the airport are evaluated. Although the evaluation has many undeterminable elements and statistical techniques are used, ultimate capacity may be expressed as a precise value, for example 57.56 movements per hour. It may occasionally be exceeded for short periods, but the implication is that operations are running favorably to achieve this value, and thus it is never likely to be exceeded, or even sustained, in service.

Sustainable capacity is the movement rate deduced from the ultimate capacity, but usually expressed as an integer value. It has been reduced by a proportion that equates to a predetermined delay and can thus be regarded as sustainable in normal operations. The sustainable capacity of a runway with an ultimate capacity of 57.56 movements per hour might be around 50–54 movements per hour.

Evaluating runway capacity

The runway occupancy time (ROT) of an arriving aircraft is determined for each category of aircraft type by combining the physical characteristics of the runway – specifically length and position/configuration of entry and exit taxiways – with aircraft performance data. The aircraft categories roughly classify aircraft by approach speed. The heavy 'category aircraft are segregated because they create sufficient wake turbulence to have a more severe approach spacing criterion applied to them.

The landing distance required (LDR) for each aircraft type is the runway length required measured from the threshold to the point where the aircraft will stop. The actual landing distances measured in normal operations always show considerable differences to what is published, as the actual distribution is influenced by taxiway positions, the relative location of the airport terminal, and – where it has a psychological impact on the aircrew – the visible terrain. It is necessary to observe or postulate the distribution of use of taxiways by each category, and then with an associated ROT value to deduce an average ROT value for the whole traffic sample. A sample in Table 7.1 presents some observed ROT values between 38.5 and 72.3 seconds and an average ROT for the traffic category of seconds. If the data in Table 7.2 referred to medium' aircraft and the heavy' aircraft average ROT was 61.312 seconds and the small' (turboprop) category ROT was 32.831 seconds, then it is possible to IARE AIR TRANSPORTATION SYSTEMS Page | 128 Source from Air Transportation Systems by Mike Hirst

calculate an ultimate capacity for the runway, provided the proportions of operations by aircraft in each category are known. For an example assumes that the proportions in heavy, medium and small categories are 15, 56 and 29% respectively; an average ROT for the arrivals in the complete traffic sample is shown in Table 7.2.

	Tax	iway					
	G	F	E	D	С	В	A
U = usage (%)	0	3	48	47	2	0	0
R = ROT(s)	0	72.3	51.4	43.5	38.5	0	0
(U/100 × R)	0	2.169	24.672	20.445	0.77	0	0
		Σ	2 = 2.169 +	24.672 + 20.	445 + 0.7	7 = 48	.056
Table 7.2 Average	ge arri	val ROT					

Table 7.1 Arrival runway occupancy times in detail

Category	ROT	Sample	Contribution
Heavy	61.312	0.15	9.1968
Medium	48.056	0.56	26.9674
Small	32.831	0.29	9.5210
		$\Sigma = 4!$	5.6852 seconds

The ROT is heavily biased towards the value used for the medium category, which indicates that it is by far the most dominant category. Provided the traffic mix is so distributed, the extent to which the average ROT will change will be relatively small. So far only the ROT of arriving aircraft has been considered. The evaluation of departing aircraft ROT values requires knowledge of access points, an allowance for line-up and the roll-time from brakes-release to airborne. It is usual to regard the runway as occupied 'until the aircraft has exceeded a height of 10 m (35 ft) or so.

Where arrival and departure movements are equal, they can be assumed to be conducted alternatively. The sequence of timings (and example timings that are indicative only) is shown in Fig. 7.5. The timeline sequences and periods are defined and applied thus:



- Tapph is the time taken by arriving aircraft to fly from the point where they are given clearance to land to crossing the runway threshold (assume 60 seconds).
- ROTapp is the runway occupancy time evaluated (use 45.69 seconds from the example).
- The departing aircraft is assumed to enter the runway after the arrival has passed its entry point (usually, but not always, the threshold).
- Clearance to take-off follows soon after the arrival has vacated the runway (assume 5 seconds).
- ROTdep is the time taken for the aircraft to be airborne and to reach the point where the next arrival aircraft can be issued with a clearance to land (assume 36 seconds).

The above sequence, if valid for the runway being assessed, takes $60^{145.69}_{5.69}$

- whether departing aircraft need to enter and backtrack the runway (and whether this time absorbed in the time taken by the arrival to pass its point of entry and leave the runway)
- whether Tapph will be larger when an arrival is following a previous arrival that was a heavy'aircraft
- whether an average ROTdep is acceptable, just as ROTarr was averaged.

These are typical issues and illustrate why simply looking at an indicative ultimate capacity figure in a reference is often not adequate to determine the capacity of an actual runway. Figure 7.6 presents some broad assessments of runway capacity values that can be assumed to apply to a number of commonly encountered airport configurations.

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In a complete evaluation, not only would local operational issues be considered but the combinations of consecutive arrival–arrival, departure– departure and departure–arrival operations be evaluated, and the probabilities of each occurring be used to factor their contributions to the whole runway operation. Large airport capacity evaluations must also take into account the interaction of runways, as six-runway airports are not uncommon at busy hubs in North America. An example airport layout (Cleveland, USA) is shown in Fig. 7.7. The associated runway capacity chart, which has become known as a runway benchmark' diagram since the FAA began to publish annual benchmark' assessments of runways in the USA, presents the arrival and departure capacity in the form illustrated by

Air	transport operat	ions – all-weather
	Movements/h	Movements/year
Single runway	50–59	195 000-240 000
Close-parallel runways	56-60	260 000-355 000
Independent parallel runways	99–119	305 000–370 000
Widely spaced close-parallel runway pairs	111–120	550 000-715 000

Airport configuration and capacity (Source: FAA capacity handbook).

Fig. 7.8. The points superimposed on the capacity _envelope' on the chart are the airport hourly demand statistics. Clearly, to cope with demand in all circumstances the demand points should be within the capacity envelope. The evaluation of data for a particular airport requires analysis of runway operations under different air service rules (essentially visual and instrument



rules, which will be discussed in the next chapter). The airport demand might also change, in that some operations might diminish or cease (either grounded or diverted) when instrument flying conditions fall below the minima imposed by operations. A few words of warning about the validity of such evaluations are essential, given the prominence the data from such evaluations exert on issues that are considered in later parts of the book. The above evaluations assume proportions of movements in each category, but most runway capacity assessments concern the future use of a runway and require estimation of the proportions of aircraft in each category. Because a runway may be configured for operations several decades in the future, at the design'stage the information available from airlines, whose horizons are often months and a few years at most, is rarely as reliable as a planner would like.

In these evaluations, it has been assumed that there is no airspace constraint applying to the runway arrival or departure streams, and the runway has been assumed to be unaffected by an adjacent or intersecting runway. The way that runways interact, and operations are affected by terminal position influence ATC procedures, so the refinement of capacity is addressed further in the next chapter. The material presented here has indicated how an initial capacity might be conducted to justify a configuration choice at the initial airport planning stage.

Sustainable runway capacity

The derivation of a sustainable capacity is often rigorously defined, but using different criteria, depending on the organization conducting the study. While the variation in answers is small these differences are hotly debated, given that an assumed extra movement per hour can amount to perhaps 16 extra movements per day on a runway or some 5000 movements per year. With income at around $\pounds 10-20$ per arriving passenger in the UK (2007), at an airport with an average of 120 passengers per movement this can affect the presumed annual revenue by as much as $\pounds 6$ million per annum. In many cases an airport will declare a sustainable capacity that is 90% of the ultimate and leave it simply at

that. The reasoning is that this results in a traffic load that experience shows ATC can handle without excessive delays. In fact, the relationship between capacity and delay is inherently complex, and is an issue that will be returned to within a more detailed explanation of ATC issues in the next chapter. An ultimate capacity of 49.08 movements per hour, using the simple criterion already quoted, would translate into an assumed 44 movements per hour per runway. Throughout the USA common runway capacity definitions have been developed by the FAA and researchers, and a similar process is being pursued in Europe, under the auspices of a project – Single European Skies (SES) – that is EU approved and administered by Euro control. This seems unlikely to adopt US airport and airspace evaluation definitions and processes, given that European operations can be argued to be different to those in the USA, but the need for a consensual set of parameters and evaluation procedures is by now a pressing requirement for airport and airspace planning organizations.

Runway pavement strength

The physical properties of runways are worthy of considerable debate and yet are accorded only a brief overview here. Pavement strength is critical to operations and is expressed by a pavement classification number (PCN). This is determined by design and is dependent on materials and subgrade depths and quality. The PCN value of a runway will tend to reduce with age (it can increase in some circumstances, for example curing concrete), but, in general, provided the PCN value equals or exceeds the aircraft declared ACN value, the operation is permissible. The aircraft classification number (ACN) is determined by the manufacturer at the design stage and is dependent on such issues as MTOW, undercarriage overall geometry, the spacing of individual wheels on a multi-wheel landing gear unit and actual tyre pressures. In general, the larger the aircraft, the larger the ACN number, but there are surprises. Professional advice is essential for operators who are conducting marginal operations, in that ACN can exceed PCN by as much as two-fold and the movement (if it is rare) will be deemed acceptable by the regulatory authority. The runway condition needs to have been regularly monitored and the airport operator has to agree to the operation. They will need, for example, to consult their insurance conditions as well as consider technical issues.

The maneuvering area

Beyond the runway and extending up to the airport terminal(s) is the maneuvering area. Official definitions exclude the apron (or ramp), as different operational conditions can apply on the apron, but the common point that is of interest here is that their design must ensure that maximum efficiency is drawn from these facilities. The apron and the taxiway/runway configurations are critical to achieving a sustainable high movement rate on an airport. Ideally there will be more than one exit from an apron to allow access/egress in the event of a taxiway becoming blocked (by an accident or through the need to perform maintenance). It is also desirable, if a high movement rate is expected, that the taxiway system allows departing aircraft to man oeuvre to the runway entry point without needing to enter and backtrack 'on the runway.

A taxiway parallel to the runway and running its full length is a minimum requirement for a busy airport (one whose movement rate will regularly equal the capacity of the airport). In ideal circumstances there will be two parallel taxiways and overtaking areas, where the order in a departing aircraft queue can be changed. These conditions can be accessed from an airport plan or photograph, and examples are shown in simple terms in Fig. 7.9.

The taxiways must be strong enough, wide enough and sufficiently spaced relative to other maneuvering regions to ensure that aircraft wheel track and turning circle needs are met and that the risk of aircraft clashing is

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Minimized. On large airports it is usual to ensure that the minimum taxiway width is 23 meters and that there is a minimum separation of 190 meters between the runway and parallel taxiways. At least one-half of this distance should be available between adjacent sections of parallel taxiways. The taxiway configuration is vital to attaining a sustainable operational capacity. The leading criteria on which taxiway configurations can be assessed include:

Runway access/egress. The more points at which aircraft can enter or depart the runway, the more likely it is that the runway occupancy time (ROT) of arriving aircraft will be minimized. Likewise, departing aircraft can have their ROT minimized by having taxiways access at the ends of the runway (already apparent in the runway capacity assessment). Turn-off geometry. Angled turn-offs, sometimes called rapid-exit taxiways (RETs), allow arriving aircraft to turn off without having to halt and conduct a 908 turn, which can take a great deal of time. Parallel taxiway. A taxiway, appropriately spaced, that extends the full length of a runway can be the most suitable way to allow access/egress and is probably essential when an hourly movement rate in excess of about 20 aircraft is proposed.

When a very high movement rate is expected, it can be valuable to have two parallel taxiways. Airfield lighting Runways have runway and approach lights. The approach lights are set along the extended centreline, with cross-bars that decrease in width (the edges aligned to meet at a point 300 m within the approved runway length) as the runway is approached. Lights are white and relatively directional. They are mounted above the runway surface level, but if they are within the runway strip and RESA they must be attached to frangible posts that will shear and not impede an object, such as an undershooting or over-running aircraft.

The most complex installations will extend 900 m from the threshold and have cross-bars at 150 m intervals and side-bars (parallel to the extended centerline lights: red and sometimes called barrettes) at 30 m intervals from 270 m to the threshold. The threshold will be marked by a closely spaced row of green lights (shining up the approach) and red lights will show down the runway.

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The runway lighting will comprise white lights along the runway edge, spaced at 60 m maximum, and for low-visibility applications there will be 15 m spaced centerline lights. The sidebars (barrettes) extend from the threshold to 300 m into the paved area, again at 30 m intervals, but using white lights. Where a displaced threshold is used, the displaced threshold will be the datum for the lighting system. The most common approach guidance lighting is the PAPI (precision approach path indicator). All lighting is so crucial for all-weather operations that they must be supported by a dual-redundant electrical power supply, so that no one power discontinuity will cause loss of visual reference. This is similar to the safety requirement applied to radio communications and naiads, but the power requirement and instantaneous switchover 'time requirements are particularly onerous. There has been widespread acceptance of solid-state lighting (usually light-emitting diode (LED) technology) as these lights are more durable and use less power than filament lamps.

Taxiways usually have blue lights at each edge and green centerline lights. Where a taxiway can lead to a runway, red stop -bars are placed across the taxiway. On large airports (notably London Heathrow) taxiways are divided into blocks, and the ground controller will direct a user along a path, terminating at a red stop-bar.

Aprons are usually well lit by floodlights, and those stands that are adjacent to terminals, especially if they have jetties to load/off-load passengers, will often have an optical guidance system. At small airports a marshal will direct aircraft to a stand using hand-held wands. These are illuminated at night. Stands have markings relevant to various aircraft types so that the crew align the doors with jetty access zones. Aircraft doors are assumed to be on the left-hand (port) side of the fuselage, with servicing and freight hold doors on the other side.

Aprons

The apron is the holding area where aircraft are parked for disembarking and embarking passengers. It must provide enough parking to cope with peak demand. On small airports this is achieved by a small hard-standing adjacent to the terminal. If the airport has self-maneuvering 'stands, aircraft will park at an angle (skewed or even parallel to the terminal frontage), and the airport is saved the chore of providing tractors to conduct push-back'maneuvers. However, due to jet-blast hazards and as aircraft size increases, and especially in countries with inclement weather, terminal side retractable jetties 'are preferred, aircraft are parked nose-in 'and pushbacks are essential. An advantage is that stands can be slightly closer together, but as terminal frontage is usually limited, the extra frontage that is needed is generated by having terminal piers, or satellites. In such cases the clearances between stands is an essential consideration affecting apron size, and if a cul-de-sac'is created, the ground movement problems can be sizeable. Remote stands, where passengers disembark and embark from buses, can be a compromise when traffic levels achieve sudden peaks.

Because aprons are concrete hard standings, they are often easily extended, and therefore do not constitute significant capacity constraints, but if apron expansion is conducted piecemeal, without consideration of the long-term impact on overall airport performance, the effect on service quality issues can be appreciable. If passengers have to wait for buses, walk longer distances, be held up waiting for baggage to appear at reclaim, and so on, the most economical development of an apron, while it might best suit what is available for the income generated by the handling fees that an airline is willing to pay, is a strategy that might be at odds with the service quality remits of customers.

A key consideration determining total stand capacity is the accommodation of based aircraft. If these are passenger service aircraft, it may be necessary to assume that the whole local fleet will be parked overnight. Some additional capacity must also be made available for visiting aircraft. This requirement can lead to exceptional extra capacity allowance. Throughout the day the number of stands needed to accommodate daily operations is related to the time required to complete an aircraft

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turnaround. In low-cost operations the occupancy can be short (25 minutes is routinely scheduled), but this can be extended by early arrival, weather and delays. Routine practice in stand allocation work is to allocate a buffer time of 15 minutes minimum between successive movements on a stand. This suggests, optimistically, that up to 1.5 turnarounds per hour will be accommodated on each apron stand devoted to low-cost operations. Routinely, intercontinental flights will occupy a stand for much longer. A turnaround in excess of 1.5 hours is not untypical with a buffer time of 15 minutes again. Some services will stay even longer if they are operating a 24- hour rotating schedule. If the aircraft is not to block useful space it is pertinent to move it, after unloading, to a remote stand, and then to return it to a stand prior to servicing and passenger boarding.

Passenger terminals

Passenger terminals are the most significant facilities on civil airports. They are tailored to specific passenger 's functions, such as arriving, departing or transferring between flights.

The functions that a typical departing passenger must pass through are check-in, security, passport check, departure lounge and gate lounge, while arriving passengers typically use passport control, baggage reclaim, customs control and then the arrivals hall, where they join their meters and greeters '. Domestic passengers are saved the need to complete passport and customs checks. Transfer passengers – not what the airport will plan for, but the preceding chapters have shown they are a substantial proportion of all passengers at some airports (and almost non-existent at others) – have to pass through the appropriate arrival formalities (which will include passport control if they have arrived on an international flight) and proceed to the departure lounge, thus joining the departure process. In some cases, they may also be required to conduct a security check, and if their baggage must be checked as well, the process can be almost the same as a full departure; in general, however, they do not need to check in. Transit passengers are often transfer 'in terms of the access they need, but the implication is that they arrive and depart on the same aircraft, so baggage is not unloaded. This might be for a tech-stop 'orrefueling. Transit passengers are not usually numerous, especially now that longer-range aircraft are in use. Transfer passengers, as the routing considerations have shown, are plentiful and can even swamp the arrival and departure (terminal) passenger numbers at hub'airports.

Airlines, as has been shown, appreciate that there are preferred times for flights, which means that most airports experience very appreciable changes in demand throughout a day. In setting up an initial assessment of the hourly capacity that will suffice to gauge the design of passenger- handling facilities, it is important to develop an understanding of the proportions of operations at an airport in various passenger categories – business, leisure, terminal, hub-transfer, and so on.

Generally, the smaller the airport, the more significant, in proportional terms, is the daily peak. Thus, chasing efficiency (in terms of the physical resources and also manpower) is considerably more difficult in airports with small passenger numbers than in large airports. The smaller an airport, in terms of annual passenger throughput, almost inevitably the less efficiently it can use its facilities

Terminal sizing

As a general rule-of-thumb, a terminal should have about 25 m2 per peak hour passenger. Although not always applicable, the US FAA, as long ago as the 1960s, devised a formula-based approach to identifying the number of people in the terminal in the peak hour, called the terminal peak hour passengers (TPHP), that could be used to set an hourly throughput design target. The relationship between the TPHP and annual passenger predictions is shown in Table 7.3. This rule-of-thumb can provide a simple assessment of terminal area (see Table 7.4).

These are indicative data, and terminal designs straddle the rough areas shown, often by large margins. There is no easy way of incorporating non passenger- handling functions, such as airline and

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airport offices. An airport designed specifically for low-cost operations in Europe, for example, might provide only 12.5 m2 per peak hour passenger, believing that dwell time in

Total annual passengers	TPHP as a percentage of annual flow				
30 million and over	0.035				
20 000 000-29 999 999	0.04				
10 000 000-19 999 999	p.045				
1 000 000-9 999 999	0.050				
500 000-999 999	0.080				
100 000-499 999	0.130				
Under 100 000	0.200				

Table 7.3 FAA TPHP and passenger movement relationship

Table 7.4 Simple assessment of the terminal area for a range of airports

Annual throughput	TPHP	Terminal area (m ²)
100 000	200	5000
500 000	400	10000
1 million	500	12500
5 million	2 250	56250
10 million	4 500	112 500
30 million	10 500	262 500

the terminal will be low and that as delays do occur and passengers are stranded, they will have to accept the reduced service quality that comes with inconvenience. The data do show that while larger airports have larger terminals, the scope for difference at any airport is enormous. A widely used assessment process is the so-called IATA level of service (LOS) criteria. This allocates space to major functions, but instead of setting a definitive figure for area, acknowledges that area and service quality are transferable. The IATA level of service (LOS) descriptions is

LOS	Description
А	Excellent – free flow
В	High – few delays
С	Good – stable flows, acceptable delays
D	A dequate – flow can be unstable, delays still acceptable, but becoming frequent
E	Inadequate – unstable flows, unacceptable delays
F	Unacceptable – system breakdown, unacceptable delays

The relationship with space in various functions is shown in Table 7.5. The value of the IATA approach is that variations on the rule-of-thumb sizing are given more association with efficient usage. Thus, an airport owner who is treading carefully between being economical and yet not

	LOS description (m ² /occupant)					
	A	В	С	D	E	F
Check-in / departure concourse	1.8	1.6	1.4	1.2	1.0	No
Wait/circulate (e.g. departure lounge)	2.7	2.3	1.9	1.5	1.0	criteria
Holding areas (e.g. departure gates)	1.4	1.2	1.0	0.8	0.6	are
Baggage claim (excluding devices)	2.0	1.8	1.6	1.4	1.2	set

Table 7.5 IATA LOS criteria

wanting to sacrifice efficiency has a first-order assessment tool with which to associate efficiency and effectiveness. The evaluation of actual terminal function service rates is often verified by using a computer-based simulation model. These are relatively expensive software tools in which the following data are enteredthe daily traffic sample (aircraft types and passengers and time of arrival/departure) a drawing of the building and internal fixtures (as detailed as possible) service quality criteria (maximum acceptable queue size, weight time, etc.).

The model runs a representative traffic sample through the system, moving entities (a passenger or a bag) throughout the modeled building, and creates reports 'on movement data or produces a scaledimensional view of the building, on which passenger movements are presented. This can be linked to gate assignments and is therefore linked to airside operations and airspace modeling as well as the landside access details; kerbs, car parks, even people movers and railways, can be modeled. Modeling tools take a long time to set up and their results deserve careful deliberation, given that they are statistically based and the quality of input data, especially for long term scenarios, is often debatable. Smaller airports often feel at a disadvantage to larger airports, as the cost of terminal simulations is less easily justifiable, given that it becomes a larger proportion overall of the total design budget.

Terminal configuration

Aprons surround a terminal, so getting access to the stands where aircraft park is a major factor in defining overall airport configuration. Airliner compatible stands can account for 45 to 80 metres of frontage. Consider a 30 million per year airport that has a 250 000 m2 terminal building. It may handle passengers and baggage on three floors and will thus have some 80 000 m2 per floor. If the building is 120 m deep the frontage will be about 650 m, which will allow direct access to between 8 and 15 stands, depending on aircraft size. With a peak hour throughput of some 10 000 passengers, if the average load is 100 people, there will be 100 movements per hour (and assume for now it is 50 arrivals and 50 departures). This number of movements cannot be accommodated on the few stands that will be directly next to the terminal frontage.

Among solutions, the pier' is a popular choice, but if it is too narrow it becomes a boring corridor. Furthermore, the walking distance from a terminal to the sixth stand on a pier can be 270–480 m. Several small piers can serve a more compact space, but this creates cul-de-sac aprons, and aircraft manoeuvring delays can affect surface movement capacity greatly. The costlier, but more flexible, solution is a _satellite'. This has to be accessed through a walkway/tunnel, often with a moving walkway) or using a railway-based system (which is usually unmanned to save on operating cost). Initially architects preferred circular satellites, but as aircraft spans have increased these have become

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congested. They are difficult to modify so the most popular concept now is _linear'satellites, which can be orientated perpendicular or parallel to the terminal facade. A 30 million passenger airport will have in the order of 80 stands and would probably use the frontage with small piers and two linear satellites. This would have perhaps

30 stands per location, and the designer would try to organize the terminal and apron so that the point between locations that 50% of passengers might use will be at a distance of less than 1 kilometer. Extended walking distances conflict with the service requirement of a passenger using a _hub', and the only solution is for airport and airlines to work closely with one another to reconcile these issues. The traditional solution is to group stands for a regular-user airline, so that their transferring passengers will find aircraft almost adjacent. The stands can become user-designated, and while the airlines will enjoy the opportunity to _brand'them with colour schemes (if they are allowed to – and why not _at a cost'?), they will have occupancy of space at some periods that might be useful to accommodate other airport users. The ability to find a reconcilable solution among so many airlines is often a management task fraught with difficulties.

Once _shape' (determining points of entry and exit on a drawing for arrivals and departures) has been scaled, the physical juxta-positioning within the envelope of the building of passenger and baggage facilities is an architectural challenge. At small airports, a single-floor terminal that is expandable by tagging extensions on each end is often preferred. As the airport develops this can lead to long passenger through-paths, and keeping passenger and baggage paths apart is often a physical challenge. At large airports the architect will often specify two or three levels, with baggage handling (and airconditioning and service deliveries) on the ground level and departures and arrivals segregated in the first and second floors. This is a popular configuration, although it requires complex landside development. Because arrivals need less space than departures some designers have baggage handling and arrivals on one floor – usually the ground – and departures on another floor, usually above so that baggage collected at check-in is delivered to the sorting area down chutes or sloping belts. Arrivals need least space because they are not held in the terminal. A good airport design will allow an incoming passenger to slip through without any hesitation. In the case of a passenger arriving on a domestic flight and carrying their only luggage this is very often the case. Most passengers have to stop briefly in the baggage reclaim area and collect their hold bags. The smallest airports often have little more than a table or a sloping shelf, but in larger airports the baggage carousel' is now a common feature. This is a segmented flat surface which is designed to slide along and even around corners. The baggage is loaded on to the belt either directly, perhaps at a location where it protrudes from the terminal, or on a belt that feeds the carousel from within the baggage handling area. A large belt will accommodate the baggage from several flights, and to guide passengers to the correct belt it will display a sign with the flight number and the place name from where the baggage has arrived. The display is one of numerous units that are scattered around a modern terminal. They are almost all liquid-crystal or plasma displays, and the computer-based systems that digest arriving and departing aircraft information will select the information to show in different places. This is tip of an information technology iceberg, and the visible element is called the flight information display system (FIDS). There will be databases of planned and actual movement information that will be analyses to obtain delay statistics, to assess parking and passenger handing charges, and so on. There is often a port on this system that feeds directly to national TV and internet links so that data can be accessed and read directly at home.

International arrivals invariably have to pass through a passport control or immigration process, and this can lead to huge queues and delays at very busy international airports. Within a region such as Europe, most EU passport holders are able to slip quickly through such formalities. Once reconciled with their baggage, passengers pass into customs, where they are usually trusted to declare goods they are importing or allowed to walk through if they do not carry any declarable imports. In some

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countries this can be a bottleneck again, some national authorities demanding, for example, to X-ray all incoming baggage and confiscating what they classify as contraband.

Departure flows are easier to visualise, requiring simply check-in, a security check and then passage through the departure lounge and gate areas. Nevertheless, the check-in area is often difficult to configure. The area around check-in desks has to be large enough to accommodate queues, and there is the problem often of finding a route from the desk to the security check without first stumbling through the remaining queues. There was a time when all airports had sections of their departure hall dedicated to user airlines, so that each company had a few desks on which they displayed their emblems or logos. This is wasteful when an airline is only occasionally using the desks. When technology permitted they were forced to use a computer based check-in desk that would change its displays and function to suit a number of airlines. This is a common-user terminal equipment (CUTE) desk, and brought better utilization of facilities and floor space to many airports. Later, the commonuser self-service (CUSS) unit appeared; this is a unit at which the passenger presents their ticket or enters booking details personally and allows them to self-check' their flight. There are two schools of thought on this system. In one case the CUSS unit is free-standing, and after validating their ticket and seat the passenger has to proceed to a conventional check-in desk where they _drop off^{*} their baggage. A member of airline staff or an agent has to print and attach the appropriate baggage tag; if there is a security requirement for questions to be asked, the opportunity is there. This dual-desk process does not use space as efficiently as a system where the CUSS unit is integrated into the checkin counter. A passenger with only hand baggage can opt to use a free-standing counter, while one with baggage to check in can use the integrated desk, where the unit will weigh the bag and print the luggage tag as they receive their self service ticket. The airline representative can again intervene, if necessary, such as when baggage is over a weight limit.

Most airports desire a spacious departure concourse with high ceilings and lots of natural light, but mixing these desires with the intricacies of passenger flows and baggage flows can often be an expensive luxury. Even then, the design has to be easily expandable, and the reconciliation of requirement upon requirement is a very difficult task.

The security check was not an issue when air transport was a mode of transport used by only a small proportion of the population, but nowadays, with threats to take explosives, firearms or other harmful devices on aircraft prevalent in many communities, the security process has become a necessity, and it seems is never likely to be absent from terminals in the future. If there are 100 check -in desks at a large airport, each capable of processing 36 passengers per hour, then 3600 passengers per hour – an average of 60 per minute - have to be checked in at the security gates. It is usual to look towards handling 4–6 passengers per minute per gate, which means 10–15 security gates. To proceed through a security channel is not always a 10–15 second process, however. It can take 2 to 2.5 minutes to remove outdoor clothes (and perhaps shoes) and metal objects, to load them into trays and to pass them through an X-ray machine. Then the individual passes through an archway metal detector (AMD) and may be subject to a body search.

They have to retrieve their hand baggage and clothing items and re -dress; thus at any instant in time there can be seven passengers in a security channel. This means that a similar number of security staff per channel are needed, and to maintain their vigilance they need time to move around and to take breaks. It is typical to roster eight staff per channel in a busy time, and that becomes a significant number of staff. It is nowadays a significant proportion of the airport operating cost. Once through the security check a passenger is _airside', and they are not allowed to proceed back _landside' without appreciating that they will have to renegotiate the complete security process again. Airport staff need to transit this invisible line many times daily, however, so a rule -of-thumb is that there should be one staff channel for every 8–10 passenger channels. These are also manned, and the checks have to be more than perfunctory to maintain a high level of security. It is usual to have closed-circuit television

(CCTV) monitoring as many security channels as possible. Indeed, security cameras, on the outside and internally, are used at all main airports nowadays, with 20 or more cameras being a typical _small' installation, even at an airport with perhaps half-a-million passengers per year. At a large airport there can be many hundreds of cameras, all with their images continuously recorded, monitoring operations. Cameras will be mounted within the terminal, over access roads and also car parks.

The departing passenger, after the hassle of check-in and security, is enticed to relax in the departure lounge. Concessions will be offered to businesses to supply food and drink, newspapers and incidental goods, even high-quality goods, and there will be the inevitable _duty-free' shopping area. At large airports these facilities reach city shopping mall proportions, and the revenue they generate is often a vital part of the airport operator's revenue. The airlines, who value their high-yield' passengers, will not discourage them from cruising these areas, but additionally they will offer socalled business or executive lounges' where they can retire from the hustle and bustle of the departure lounge. They provide free refreshments, spacious and comfortable seats, and may offer a personal call-to-flight service. The ability to do work using laptops and internet links has been indicative in recent years of how the airlines will innovate to offer a better quality service, but they have to pay handsomely for this space. These have not been the exclusive preserve of the departing service either, for in recent times airlines have hit on the idea of providing a reception service to disembarking passengers, where they can shower and change into laundered clothes, thus arriving fresh at business meetings. Airports dislike these continual calls upon valuable space, but can be encouraged to provide the necessary facilities when the appropriate charges are agreed. Overall, the airport can become a significant proportion of airline costs for business passengers.

The final part of the departure process is the aircraft gate. In ideal circumstances this will be a lounge area near the aircraft. The passengers are called there by the _boarding call'- which in some _quiet'airports will be on the FIDS only – and congregate for the final time before leaving the airport. In some countries a final passport control check is conducted, usually on entry to the lounge, and finally they have to surrender all but the stub of their boarding pass as they pass out of the terminal building. Airlines are obliged to reconcile the boarding cards they collect with those issued, and the aircraft cabin crew will conduct a passenger head count too. This is all a part of the safety culture, unheard of on other modes of transport. It is vital in aviation to know exactly the _souls on board', and if a passenger fails to board, the airline – even if it causes a significant delay – will unload and retrieve the passenger's baggage. This is not done in the name of service quality; it is done because the opportunity to load unwanted devices in unattended baggage has to be eliminated.

Most airlines vie to park their aircraft on a stand that has an _air-bridge'(or jetty) to the gate lounge. This retractable tube can be steered to mate with the aircraft door, and at some airports the transition from terminal to aircraft is almost invisible. Where it is necessary to park aircraft on _remote'stands, however, passengers embark and disembark using steps – either driven alongside, or are retractable from within the aircraft (sometimes called _air stairs') – and are transferred between the stand and the terminal using buses. At airports where there are no air-bridge facilities passengers have to walk to/from the terminal and aircraft, which is potentially hazardous, so airport staff and airline representatives are forced to stand at strategic points on the route and erect temporary fences to prevent passengers walking into harm's way. All staff working on an airport apron have to wear a high-visibility jacket; at strictly run airports, failing to adhere to this demand is a punishable offence, and persistent offenders can be dismissed. All this is done in such a way that the majority of passengers never notice the procedures that are being invoked to ensure the safety of themselves and others.

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Arriving passengers are directed to different doors from those where departing passengers will emerge. Where there are air-bridges, there are often adjacent fixed sections of the tubular walkway that gently slope down from the departure gate lounge or from the aircraft to the arrivals hall. The entrance to these tubes can be opened and sealed by the ramp staff. These are indicative of the detail that can characterize facilities that assist an airline's need to conduct a quick turn round.

The terminal processes that have been described have to be conducted strictly according to a timetable that is built around the scheduled arrival and departure times of aircraft movements. If an arriving aircraft is delayed the consequence is that passengers will be left longer in the departure lounge and gate areas. Usually, an airport will not encourage the airline to call the passengers to the gate until they are certain of the movement's occurrence.

There are two reasons: first, they keep the passengers in the most spacious part of the terminal and, second, they are kept where the concessions are continually accessible, as this all adds to airport revenue. Sadly, when delays occur that are not of the airport's making this can lead to great congestion, and it is ironic that an airport is often the beleaguered site upon which the media and passengers heap condemnation at such times. There are many airport staff who can recall heroic efforts to alleviate the effects of imposed congestion and whose efforts have been vilified rather than thanked. The airport, when under stress, is not a place where the faint-hearted should seek employment.

Airport demand, capacity and delay

Many of the considerations above have centered on capacity issues. The fact is that airports are notorious bottlenecks, and the reasons why, by and large, have been presented, alongside the fact that many of these reasons are outside their area of influence. Airports are treated as a resource, and thus can rarely ever be optimized, and yet they have to accept also that they are often the fall-guy for other people's inadequacies. While that is true in general, there is some fine and well-run airports, but finding one that is large and successful, and that is generally liked, is rare indeed. When it does happen, and Singapore's Changi Airport would be the first on the list of customer-friendly airports, the fact is that the small state of Singapore grew by 4% just to accommodate Change, and the market it serves has been economically buoyant and predictable, thus precipitating the airport's birth and supporting it throughout its life. The airport was also designed to accommodate the needs of Singapore Airlines, which gave the airport goals that they shared and evolved in consort. A similar symbiosis is evident in the way that the airline Emirates has worked with its base airport, Dubai, and that model seems set to be replicated again in Doha with Qatar Airways and in Abu Dhabi with the airline Etihad. So why did London Heathrow and British Airways or New York's Kennedy and the erstwhile Pan Am not hit on the same formula? The answer is they could not, if they were to be open to the free market. Every airline wanted to use these places and the two cities quoted had to resort even to multiple airports, which mitigates against efficiency for an airline if it has to disperse its resources across several sites. Kennedy had a set of terminals that some major airlines designed, owned and ran. This was almost unique, and it was not just wasteful but also a legacy that has caused considerable concern. Not least of these concerns is that the emblematic TWA terminal has proved difficult to expand and yet is subject to a preservation order. Heathrow, on the other hand, having embarked on Terminal 5 will, in the wake of its opening, face few cries from preservationists when it begins to tear down the 1950s Terminal 2 in 2009. Changi, it has to be said, has remained _open' and has served all comers well enough still to win praise, while serving Singapore Airlines perhaps best of all.

This review of what airports do, and what they have to respect in doing it, is by now a familiar tale, because like building aircraft or running an airline an airport has to balance financial viability, respect statutory obligations, be efficient and meet demanding service quality requirements that will be regarded overall as indicative of service quality. Capacity is at the heart of the efficiency arguments and effectiveness is one way of expressing the degree to which this aim is sometimes compromised in the quest for acceptable levels of service quality.

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Delay is probably the most important quality-of-service indicator. Minimal delay is preferred, but attainable only at the price of having excess capacity (at other than peak times) and thus at extra cost to the airport user. In the competitive modern airport environment not all passengers are willing to pay the price. It can fall on the airport operator to find ways of accommodating high-price (executive or business) streams alongside the traditional _mass' passenger handling facilities and charging the airlines a premium (which they pass on to the customer) for the privileges obtained. Some airports choose not to support this kind of service and make themselves attractive to _low-cost' or _no-frills' operators. While people tend to buy a ticket from an airliner and associate the product brand with that service provider, they too depend in many cases on suppliers and the airport is perhaps the most important of all.

Airports have particular dilemmas:

- While they do tend to be attractive to the community, people living close are likely to complain about noise and other forms of pollution, and yet people living further away will clamour for surface transportation links that assure them of good access (and that, in themselves, can be regarded as sources of pollution).
- Airports that serve tourism may be adjacent to areas of great natural beauty, but they must not destroy the qualities of what they set out to serve. Even so, airports have to be sited so that local terrain does not interfere with safe operations. In striving to ensure that adequate safety will be assured, limits are imposed that simply constrain the ability to operate them intensively.

While it is commonplace to demand that airports have to run as businesses, if the aeronautical revenue is limited, the only alternative is non-aeronautical revenues. Many airports have become, in addition, places that will be used locally as shopping malls and business parks, to name just two popular ways of stimulating their financial status. Nevertheless, the prime purpose of an airport is to offer air transport links that will serve the community. While few airports are developed from scratch, the criteria for selecting a site for an airport deserve some thought.

An airport is generally expected to thrive if:

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- There is a substantial local community.
- The economy is buoyant (population disposable income and age distribution data can be indicators crucial to success).
- There is good surface access from roads and public (rail or road) transport support (these can cause an airport to be favored over any local competitor).

The check-list mirrors what any airline planner would muse over in looking at existing airports for regular scheduled service operations. Airports that depend largely on leisure traffic are equivalently attractive, but instead of looking at the total population an assessment should be made of local area access to leisure accommodation, the quality of accommodation and the ability of aircraft to reach regions from where holiday-makers would embark to use such facilitates. An airport can also do a lot to boost its attractiveness to operators. Itshould consider:

- a. Thequality 'of its services (in simple terms the space, convenience and overall condition of facilities)
- b. The ability for airlines to carry passengers through on connecting flights (transfer passengers) the provision of cargo and freight aircraft handling facilities
- c. The provision of facilities for aircraft ramp maintenance and engineering overhauls
- d. the attractiveness of the airport as a major operating base for an airline, or airlines, acting perhaps as headquarters, and being the base for staff training, maintenance, etc.

If airlines take to an airport it will, subject to planning consent, soon begin to develop other roles, such as:

- a) Attracting support businesses, which could be cargo forwarders, cargo distribution centers, etc.
- b) Generating industrial development centers; warehousing and distribution tends to be preeminent but could also be manufacturing (even aircraft production!)
- c) becoming a local transport interchange complex, where the network of road and rail
- d) Connections might eventually carry more local passengers than airport users and lead to a commercially attractive landside community.

Finally, if there is an overriding need for an airport – usually a socioeconomic need for a remote community – there is a possibility that it will survive under a subsidy scheme, whereby the national government regards the price paid to maintain an uneconomic business is good value for the community overall. Examples are Norwegian coastal airports and the Highland and Island airports ofScotland. This is not uncommon, but it can still be controversial.

This chapter has reviewed what airports set out to achieve and the tenets that will shape them as commercial and operational entities. To develop as airports they need to meet a number of requirements, operational in many cases and regulatory in others. This chapter has set out some of the main principles that govern how an airport has to meet the requirements for viability, compliance, efficiency and effectiveness.

AIRLINES

Abstract: This chapter explains how airlines serve demand and provide capacity in a manner that suits the capabilities of their fleet of aircraft. Airlines aim to operate viably and to set standards that will be a stiff target for any competitor. In responding to economic forces, airlines frequently change their operational principles, but they keep close to a brand'image. Airlines are where people seek the product they want and with whom they enter into a service agreement. This chapter unravels the issues they vie to balance and presents them as attributes that can be grouped in a way that is compatible with other system elements.

Key words: airline objectives, route and fleet selection, aircraft operating costs, yield management, passenger service quality, airline scheduling and timetables.

Introduction

Airlines can be like cities, in that, in terms of what they do they are all alike but compare any two and the variety of different experiences can be remarkable. There is close to a guarantee that the attributes of such experiences will change over time, so revisiting will bring recognition of changes. Sometimes this is welcome and sometimes less so. Within the community of airlines, some have succeeded in keeping their brand over many decades, but usually the only real _constant has been their colour scheme. Beneath the skin, most airlines change the principles on which they operate frequently. Some move rapidly, often changing direction in a strategic sense as they respond to economic forces, and some oscillate between service concepts as they vie to try what is new but seem reluctant to dismiss what has served them well in the past. To the public, airlines are the industry 's facade. They are where people seek the product they want and with whom they eventually enter into service agreement. Somehow a way must be found of describing what it is that drives these businesses, which all do the same thing but often so differently.

Setting up an airline

Setting up an airline invites some reflection on what common ground can be identified. First, an airline must have an owner, or owners, whose interest will be largely financial. If the ownership is private, long-term profitability can be expected to dominate commercial strategies, but if the airline is in public ownership it might have a remit to meet socioeconomic objectives and qualify for subsidies. For example, being a _flag carrier' for a small or less than prosperous nation can be an unprofitable
business, but if the reigning government believes that the losses it underwrites on the airline balance sheet are offset by positive contributions within its wider remit, which can include deterring foreign airlines from diluting the national economy by siphoning revenue into their own economies, they will often support such a venture. Second, an airline must decide where it will be based. In terms of regulatory oversight, it is essential that an aircraft operator applies for a license to operate in and around the area of jurisdiction of an aviation authority. The airline will thus have aircraft registered in that nation or within a nation that is recognized as offering the necessary regulatory approvals. This process cements an airline into the regulatory environment. In setting up their operation they are now obliged to keep their core functions transparent to the regulator. The initial requirements are simple – declare ownership, base and mission statement. Then the regulator wants to know who will hold key posts, and they will want declarations of flight purposes, typical destinations, aircraft types and technical documentation, such as aircraft flight manuals and individual aircraft maintenance histories and schedules. The process of licensing an airline takes considerable regulatory effort and is a substantial up-front cost. The aim is not to impose bureaucratic largesse, but to ensure that, from day one, safety is given as much forethought as financial performance. In most counties a brand -new airline will take six months or so to set up from scratch, although devolving an airline from an existing operation, either through expansion or post-merger or bankruptcy, can reduce this estimate to a few very busy weeks.

The financial and operational objectives of an airline will arise from knowledge of issues that have been addressed under the term natural environment '. There will always be demand for air services, wherever they are proposed, but the circumstances of each possible service have to be understood. The proposing airline must ensure that the demand is substantial enough to justify an operation and that facilities compatible with demand are available or put in place. In the latter area an airline begins to tread in airport and airspace issues, and while the constraints in these areas are of concern to an airline, traditionally the solutions are regarded as beyond their concern.

What an airline looks for in an airliner has already been debated in Chapter 5, but the route to the issues that have been discussed can look very different when they are viewed from the airline's perspective. Intrinsically, airlines, from the knowledge they have of the services they want to offer, will look for an aircraft that has the kind of performance they want. This means that they will associate performance with payload and range capability, speed and thus time between origins and destinations, and seat-km operating costs. The latter is the source of most debate, in that, as has been shown, the airline can influence the actual cost by choosing what utilization they will aim to achieve, how many seats they will install, what customer service features they will underwrite (which might extend to taking control of the passenger's comfort in periods prior to, and beyond, the actual timethat they fly on the aircraft) and what direct costs will arise from decisions that they take. This can be influenced by choices of salary scales, aircraft lease or purchase agreements, technical and customer service subcontracting, advertising and marketing, and so on. Airlines have considerable freedom in these areas, and it is where the ethos that will make them a different, or not, flying experience willreside. It is unkind to paint a picture that presents the airlines merely as aircraft shoppers, but beyond influencing what is put on offer they do tend to consume technology ', buying and using what they can get to suit their own purposes. They monitor their own performance, as a service-provider, dissect the consequences of actions and initiatives - both their own and those of others – and keep an eye on what technology has to offer. They will encourage their suppliers – of aircraft certainly, but all the other supporting players in their sales and service supply chains – to match their shopping ideas with solutions that are more innovative than they were hitherto. Airlines therefore can stimulate the adoption of new technologies and they expect engineers to sell them their ideas based on financial andservice quality benefits. Airlines are not easily swayed by innovation alone. They are increasingly aware of the fact that new perspectives are necessary and they willingly embrace _change', but are also aware of the fear that comes from entering the unknown.

Planning is often hemmed in by constraints that arise in _operations', which can be the airline way of segregating limitations that are imposed by airports and airspace providers. Some airlines groan that these are sources that are external to their remits, and while they will campaign for change they contribute nothing. More mature managers and analysts gauge ways to react to these problems. Their attitude, typically, is contribution rather than confrontational, and it is that kind of spirit that needs to be rewarded in the fullness of time. The progress that they contribute is possible only when common indicators are identified and long-term action plans that will serve the needs of the user and not place impossible demands on the supplier have been expressed, addressed and rectified. This is an area of endeavor that requires an understanding of the processes and capabilities that affect all the contributors to the overall air transport system. For now, keeping within the airline domain, their service requirements have increased in complexity gradually over time. In simpler days, an airline manager was regarded as the custodian of a noble and prestigious business. An airline set levels of expectation for their customers that heralded adventure and had romantic inclinations, and they were high-profile businesses that demanded headlines when they set out to offer new travel experiences. Many airlines still want to promote themselves as inhabiting this lofty regime, but as the breadth of usage has increased the range of business strategies has opened greatly. There are scheduled carriers that cater for business and low-cost demand or who specialize in leisure travel, and there are evencarriers that try to appeal across all these categories. Nowadays airlines fly billions of passengers annually, and while they can be broadly pigeon-holed as _flag', _private' or _public, _scheduled' or _charter', _low-cost', and so on, they are far from simple businesses. The fact that the _model' for anairline has broadened so much, and that the change process has occurred largely on the tide of technological influences that have reformed media and public habits throughout developed and developing societies across the world, testifies to the fact that they are also among the most modern of businesses. The metamorphosis that has characterized recent decades seems sure to continue. Some cherished working practices will persist, but newer working practices will arise as time goes by. Integrating these into a business scene that is forever more complex, and thus tends to be less amenable to change, is a challenge of utmost importance to the businesses involved.

Modern airline objectives

Aircraft have always won over other modes of transport by offering a _faster' (and more convenient?) way to travel to/from destinations. Because of their service speed and convenience, they over too railroads as the preferred way of conducting _long-distance' travel throughout Europe and North America. Payload expansion has also been a continual objective, with the belief, almost enshrined and partially demonstrated to be true in consideration of aircraft attributes, that the bigger the aircraft, the lower the average seat-km cost. Airliners designed to serve specific market segments have got bigger with each generation, and as airlines have sought to serve more routes, the financial properties of the operating businesses have grown at a faster rate than the size of the aircraft they use. Meanwhile, the price of air tickets has reduced, in relative terms, from enormous to almost trivial (but marketing techniques can disguise like-for-like).

In an economic business, efficiency is not as easy to define as it is in engineering, where attributes often sit on a 0 to 100% scale. Some of the physical constraints on operations can be viewed and expressed through equivalent windows, a prime example being aircraft utilization. Flying an aircraft only 8 hours per day (about 2500 h/year) has been shown to increase operating costs considerably over flying an aircraft at double this rate. The operating cost is affected by so many variables that the improvement is not as simple as saying that doubling of one leads to halving of the other. The way that service support is organized and costs are distributed can have a bearing that will affect operating cost, no matter what the annual utilization figure might be. Some efficiency indicators have to be found, but there are few parameters that will yield a recognizable datum in this complex field. Service effectiveness is an even more difficult issue to enumerate. Consider the way that the number of seats

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can be increased or decreased in an airliner's cabin. The impact on operating cost has been seen to be considerable already, but the relationship here is complex, with the efficiency and effectiveness impacts following different paths, and offering _windows' of opportunity that an airline can choose to exploit fully or partially, in conjunction with pricing and marketing strategies. The seating plan shown in Fig. 6.1 exemplifies a 380-seat three-class (12 first, 54 business and 314 tourist class) cabin plan for an Airbus A340-600. It is a configuration that would be suited to long-haul operations. If the seat data for these configurations are used and a nominal \$54 000 operating cost figure for a 12-hour operation is assumed, the revenue requirement of each seat is as shown in Table 6.1. (The operating cost has been proportioned across cabins on the basis of proportion of cabin length occupied: 9.6% first, 20.2% business and 70.2% tourist.)

The 100% seats filled data are where a strategist will begin to assess actual operating costs. This means that an airline using the 380-seat cabin will expect the total passenger load to contribute \$142 per seat on the flight. They might pay more than this or less than this, and some seats might not be

PASSENGER SEATS (380 TOTAL) 12 FIRST CLASS 54 BUSINESS CLASS 314 TOURIST CLASS



Table 6.1 Seat revenue requirement to cover the operating cost: hypothetical operation

			Load factor		
	100%	90%	85%	65%	45%
380 seat	\$142	\$158	\$167	\$219	\$316
380 seat:					fille
314 economy	\$121	\$134	\$142	\$186	\$269
54 business	\$202	\$224	\$238	\$311	\$449
12 first	\$432	\$480	\$508	\$665	\$960

the 90% seats filled value quotes (\$158) would be a nominal ticket price for a low -cost operation. The three -class case shows a more detailed assessment with a nominal ticket price for each category derived on an expected proportion of seats filled. The process has shown a way of justifying the kind of fares that are encountered on a daily basis: for example low-cost operator \$158 (90% load factor) and scheduled operator \$960 for first class (45% load factor), \$311 for business class (65% load factor) and \$142 for economy (85% load factor). Among other parameters that are also used routinely to express efficiency are measurements such as passengers (or passenger-km) per employee, but care needs to be taken. For example, employee data can be skewed by the use of subcontractors. Another

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widely used indicator is the passenger average load factor (percentage of seats filled per flight), which has already been introduced.

When airlines take account of the passenger's perception of value for money, they are viewing service quality indicators. For example, delays are related to dispatch reliability and are a prominent technical benchmark, but there can be many others. Among those exemplified above are the size of seats and the relative level of fares, but often viewed internally and rarely discussed in the open is the frequency with which people are refused a seat or are told that a flight is _overbooked'.

Over a number of decades the changes that have affected strategy have emerged from technology – in aircraft, in support services (especially concerning computerized ticketing and reservation systems) and within the community (through improved media access and the ubiquitous _internet`). These developments, and some that have not yet been envisaged perhaps, determine how managers set out plans that will meet mission objectives. It is that process that will be used to structure the next few sections. They will look at route selection and development, at aircraft selection (fleet planning) and fares policies alongside scheduling and other operational issues. Finally, efficiency and effectiveness, according to some of the criteria already recognized, and the way they can be expressed and measured, plus the inevitable question of financial success, are considered.

Route selection and development

In _deregulated 'countries the right to fly a route is entirely at the airline's discretion, subject to there being capacity to handle the required movements at the departure and destination airports. Meanwhile, operations between nations are still constrained by bilateral agreements, whereby many airline service parameters, such as destinations, frequency of service (flights/day or week), capacity (seats/week or even seats/flight), facilities offered (drinks and food, entertainment, etc.) or price, can be stateenforced through a common accord. All such restrictions tend to be politically motivated, and the belief is that they are constraints that will be removed in the fullness of time. This has always been optimistic, but the walls have begun to crumble since about 1980.

Airline traffic forecasters take such issues into account and devise route structures that they will negotiate and thus provide. The process of traffic demand modelling has already been explained (Chapter 2). Summarily, it might be an extrapolation of historical data or a model-based estimation process, validated against historical or comparable route data, and it might include assumptions on market-development trends. However it is generated, the traffic forecast is the bedrock of an airline's plans. If a company is gambling all, there is sense in setting up independent traffic study investigations and ensuring that there is sufficient correlation between results to provide an assurance that the commercial risk is well understood. Routes can radiate to and from a hub (most _national' carriers) or a large airline might have several hubs (typical US _mega-carrier'). These are hub and-spoke route structures and are the most common route structures in use today. In the pre -jet days, when long-haul travel was a laborious affair, there were stopping points en route, creating a so-called linear route structure. These are almost defunct nowadays. One reason for wishing them goodbye is that scheduling the use of seats on individual sectors is a nightmare.

Variations on hub-and-spoke that are commonly encountered include the _round robin'. This is a service where there is an intermediate stop, such as a route from A to C via B. If B and C are relatively close the return trip might not be conducted back via B, but direct from C. A further variation is most frequently encountered when a new _hub' is being established, which will serve destinations already visited from an existing hub. In this case the aircraft flies from A to destination B, then from B to the new hub, then back to B, and finally returns to A. All the crewing and maintenance resources might be at A, and thus the new hub's potential is tested with minimal



Route structures and scheduling variations.

additional capital or infrastructure investment. This is called a W-schedule. These are illustrated at Fig.

The most significant way that airlines have stimulated demand is by stimulating the use of its main base as a transfer hub. This means attracting those passengers who fly from B to F via their own base, location A. In the circumstances being considered here the belief is that B to F via A is a travel option that will appeal as much as flying from B to F directly. Two issues will influence the passenger's choice – time and cost. This has been discussed in Chapter 1, where the interest was on the comparison of properties of different ways of serving locations in a simple nine-airport system. Route planning requires that suitable routes are selected, that the right aircraft type is selected and that a schedule is constructed that will provide the transfer passenger with convenient connections. It is not _routes' alone. A further caveat is that, ideally, the destinations should be at similar distances (or roughly multiples thereof), as in operational terms the similar flight times will create interlocking schedules.

As an example of how interesting, and sometimes surprising, the results from a hub analysis can be, consider the idea of offering hub-and-spoke routes in Australia. If one looks at the geographic and distance-related attractiveness of routes in terms of avoiding acute angles between services and getting a small spread in route distances, the best hub location to choose is Alice Springs, in the center of the continent. Analyzing Australian airports using a traffic model to generate expected demand for direct services between the airports shown and five other Australian airports (Adelaide, Brisbane, Hobart, Cairns and Darwin), and then using the same data as a reference to assess the percentage attractiveness of hub services considering Perth (PER), Alice Springs (ASP), Melbourne (MEL) and Sydney (SYD), the apparent case for Alice Springs soon collapses. Maps are shown in Fig. 6.3 and the traffic data are presented in Table 6.2. The highlighted numbers in the table represent the best result (maximum or minimum appropriately) with regard to the parameter on that row. The combined passenger data show the number of passengers that would use

Hub airport	ASP	PER	SYD	MEL
Route data (km)				
Average stage	1817	2882	1591	1539
Standard deviation	365 527		1026	961
Basic passenger data (passengers	/week)			
Direct services	14 895	16342	28583	26902
Maximum hubbing potential	26 055	7436	31759	34 458
Combined passenger data (passe	ngers/week)			
Direct + (100-70%)	30 264	16342	46825	50976
Direct + (100-60%)	34 257	16723	54656	53305
Direct + (100-50%)	36 369	16723	55881	58238

services that the angle between services has suggested could attract either 70% or more, 60% or more or 50% or more of the direct service expected passenger flow.

In terms of which airport accumulated the highest number of best results, Melbourne seems to be the best airport, but it would be a brave analyst that suggested that it has a clear advantage over Sydney. The two are very close indeed. Alice Springs, meanwhile, shows the expected advantage in terms of a low standard deviation and it picks up, proportionally, a lot of transfer traffic, but there is nowhere near as much passenger demand as there is at the two large cities. Perth is revealed as the most remote city to all the other communities and therefore the least attractive hub location at which to perform domestic service transfers in Australia.

This is an example of a systemic process model. It has tracked attributes of the service characteristics of each possibility using a consistent analytical approach and concentrated on factors that can be related to efficiency and effectiveness. It is not dissimilar (although certainly simpler) to the kind of analyses that are conducted routinely by airlines, to determine their future route planning strategy. One example of its simplicity is that the distance between each set of airports has been treated as a set of direct (or great circle) distances, whereas aircraft often fly longer distances, as they use routes that are based on radio nevoid locations and are not direct. When the overall distance between airports is large this is not a significant issue, but viewing smaller distance operations in Europe would be very different. Nevertheless, as an example, it shows that selecting a _hub' is a vital consideration.

Where the airline's operational region is a much less self-contained community than in the example, as is the case in Europe, the route analysis is more complex. For example, considering Western European destinations that are near the Eastern European boundary and ignoring demand from outside the target region will fail to recognize demand to/from Eastern European locations that travels overland to use the airline's services. The amount of such demand is unlikely to be the same over time, and in the example quoted demand tended to rise considerably as the _border' countries became European Union (EU) members. This is an example of how any traffic forecast will be valid at a point in time but will then need to be updated, with the assumptions incorporated within them fully explained before an airline plan is built upon the potential they express. Route development will consider the social, economic and political factors that influence demand, showing that traffic forecasting is much more than just a set of mathematical equations. The judgement that is exercised in creating a forecast can be crucial to its realism, and thus its value to the user. It is the application of such skills that often can give an airline an edge over a competitor.

Be aware that once they reveal their hand by publishing their new destinations list, an airline effectively loses the element of surprise. It should be no surprise, therefore, to find that traffic forecasts and route development plans are invariably treated as commercially sensitive information.

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Airline fleet planning

Once the routes are recognized, a key decision is getting the right aircraft for the job. Among aspects that must be considered are:

- 1. The aircraft should be large enough to offer a reasonably competitive seat-km cost.
- 2. However, it should not be too large as service frequency must be acceptable.
- 3. It should be fast enough to offer a competitive block time.
- 4. It must be comfortable enough to win passenger acclaim. Some issues have already been described, but these are not universal.
- 5. It must be able to fly the necessary range, with adequate payload, using the runway(s) available, in all likely weather conditions and at all service destinations.

The aspects of aircraft and airline operational planning that determine the detail within these areas of interest have been introduced in earlier parts of the book. The complexity therefore of the task of finding the best-suited aircraft type is clearly more difficult that just simply getting _ticks in boxes'. In most airline evaluations, and because of competitive pressures, seat-km cost is the most influential selection parameter. The second most important parameter is usually payload–range. The rest are less important, but they are still critical to getting the quality of service, and in some cases, such as when a constrained hub airport with a short runway is used, that issue could climb to the top of the pile.

In evaluating an aircraft, an airline will generate data on stage lengths and loads (largely passenger numbers, but there could be significant amounts of freight to add), and look for associated payload–range and operating cost data. The former is almost set by the design, the issues governing payload and range trade-off having been explained in Chapter 5. The operating costs subject, to some degree, to airline discretion, because it can be influenced by:

Note that although a quasi-static view of fleet planning has to be taken, an actual airline evaluation will use forecast data that will incorporate assessments of traffic change over time. Thus, the expectation of rapid change could mean that it is necessary to buy slightly oversized aircraft and to make adjustments, perhaps in aircraft seating arrangements, as the airline expands. In dynamic fleet planning the number of aircraft needed year -on year will be predicted, and an order for examples of a type is placed with the manufacturer. Then options are added, with preferred dates of conversion to orders. If the market shapes up differently to what was expected, requests will be made for options to be exercised early or deferred. An airline and an aircraft supplier, and even some of the major subcontractors, such as aero engine manufacturers, are often teams that are closely knit. Annual utilization and aircraft size the criticality of annual utilization to operating cost has already been addressed. The point has been reached where this topic becomes a part of the quest for getting the right sized aircraft for the job, so it is a topic that can also be associated with payload-range capability, which an airline, ideally, would not wish to be the case. Size, in terms of nominal passenger capacity, has an impact on service frequency. In business traveler operations a daily outand-back service is the minimum that customers will tolerate. If it falls below that frequency, the passengers are likely to find an alternative route, even if it is not direct. Thus, the number of flights per week per service that are used in planning a fleet determines a lot. A simple guideline is the numerical data shown in Fig. 6.4. This shows that 10 flights weekly is the minimum for an out-andback service on weekdays only for a regular airline operation. This is not always achievable when a service is new or the destinations are a long distance apart. The question will arise, in such a case, as to whether a smaller-capacity aircraft is available, and will suffice, or whether a round-robin or Wschedule solution should be used.



Daily and weekly flight frequencies.

The opportunity for airline planners to fine-tune their options is considerable. Assume that an airline forecasts a demand for 500 passengers, one-way per day on a route. They can accommodate this in several ways:

100-seat aircraft 5 times daily = 100% load factor 100-seat aircraft 8 times daily = 67% load factor 150-seat aircraft 4 times daily = 84% load factor 150-seat aircraft 6 times daily = 56% load factor 250-seat aircraft twice daily = 100% load factor 250-seat aircraft 3 times daily = 67% load factor 500-seat aircraft once daily = 100% load factor The load factor (percentage of seats filled) has been

The load factor (percentage of seats filled) has been calculated on the assumption that demand will be unaffected by service frequency. This is not true. A more frequent service will offer more flexibility, to all categories of travelers, and will be more appealing. The operating cost per seat will also be a function of the size of aircraft. For example, the larger aircraft (assuming it is as well utilized as a small aircraft) will offer more opportunity to sell seats at a lower price.

This is where a book has great difficulty in showing how such decision making is handled in a business. A written explanation has to treat decision laden topics in a sequential manner, but in reality decisions are taken in parallel with others in the airline planning chain of command. There is plenty of scope to accommodate an iteration of variables such as fares, seat numbers, service frequency and consequently air craft size. In systems thinking terms this has been identified as _joined-up' thinking in recent years, but here is evidence that it is not a new idea. There are many innovative solutions, some of which have passed the test of time and others that have not. A simple example of a ploy for providing better _value' but still having flexibility in an aircraft is to have a cabin where triple seats can become double seats with a central table, simply by folding down the seat back.

When seat requirements do not match frequency, a common solution is to use different aircraft types – smaller aircraft on the _thinner' routes – so that a consistent frequency of service is maintained. This option is only possible in large airlines, where large common fleets offer such advantages as scheduling flexibility, but they have become more common in recent years. A solution for a large carrier is often to _franchise' the _thin' routes to a regional aircraft operator. To reduce variable costs on the small aircraft, they might be persuaded to operate with a common livery, to have common flight codes and to use the parent company's ticketing, reservation and advertising capabilities. The impact this has on indirect operating costs is addressed in more detail later.

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Seat category	Sample	Min-max pitch (cm)	Average cm (in)
First	28	90-231	197.0 cm (77.6 in)
Business	126	86-198	140.8 cm (55.4 in)
Economy	159	76-94	81.5 cm (32.1 in)

Table 6.3 Surveyed range of seat pitch dimension on several airlines (Source: Business Traveler 2007)

Seating arrangements

In terms of seating, aircraft can be categorized under two broad headings: wide-body (or twin-aisle) and narrow-body (or single-aisle). Single-aisle aircraft can have between two and six seats per row, with the aisle near to the center (maximum headroom) portion of the cabin cross-section. A six seats per row single-aisle layout will have three seats either side of the aisle. This is the maximum number of joined seats that passengers will expect, but the overriding driver might be from safety regulations, because in reviewing the aircraft during design, limits will have been imposed on numbers of adjacent seats and the distance to an exit from any point in the cabin. The aim is to minimize the likely time to evacuate the cabin. These criteria are applied to all aircraft, and on a wide-body aircraft they usually require that there are two aisles, and generally impose a limit at 10 seats per row. Multi deck aircraft are subject to additional constraints, but these apply, so far, only to the Boeing 747 and Airbus A380. Seat size can vary greatly too. The data in Table 6.3 illustrate the great variation in seat pitch that can be experienced throughout a number of airlines surveyed in 2007.

There is little reason here to delve into the relative values of having more or fewer toilets, or bigger or smaller galleys. Nevertheless, these are issues on which an airline will make considerable judgement; while they are not parameters that routinely will determine whether or not a passenger buys a ticket, the airlines know that they are factors that will impact service quality aspects that especially frequent travelers will take into account. Because these parameters influence choice, they are significant.

Indirect operating costs

There are several airline ownership models, ranging from one where everything that is used is owned and where staff are employed to conduct everything _in-house' (which is the way it was done by everyone until the 1960s or so) to one that leases as much as possible and subcontracts as much labor as possible (which, to an extent, is the way that airline businesses are more often configured nowadays). The former is the model that ensures greatest control over labor, but it is inflexible. Thus, when circumstances change, the airline often has an inertia that sees expenditure maintaining a steady course while the revenue is plummeting. By using subcontracted labor the airline has all the components more loosely federated (in a business sense) and has a greater capability to redirect resources, and thus to tailor expenditure and revenue. This promises a better likelihood of survival in a turbulent business environment. Some permanent employee positions are unavoidable. These include those associated with the airline's operating license, an executive-level _board' to conduct strategic management and individuals who will contribute to continuity of purpose at all stages below executives – ranging through middle management, supervisory and _production' levels. It is usual to classify employees in categories that can be associated with roles, such as administration, finance, flight operations, station management, and so on. However, take a list of airlines and their employment data from any reputable source and try to analyze it objectively; the chances are that you will find little correlation in the way they apportion staff to various functions or duties. There is tremendous diversity in the kind of operating models that are used.

E- commerce has been used to reduce indirect costs in almost all airlines, but the most significant examples have been in low-cost airlines, where indirect costs were, initially, only a fraction of those of traditional airlines, largely as a result of internet booking. Various passenger categories will enumerate different benefits and dis-benefits from such developments, and the answer as to what is right or wrong is not easy to distil. The established airlines have tended to take a leaf from the low-

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cost operator book by opening internet bookings, for example, but they often retain the traditional travel agent and telephone enquiry and reservation options, especially for business travelers.

Aircraft: buy or lease

In the last few decades it has been more commonplace for airlines to avoid the capital expenditure involved when aircraft are purchased directly, by leasing their fleet from an intermediary leasing company. The theory is simply that, as aircraft are very expensive, they lock money in assets. If the aircraft can be leased, the lease costs can be repaid from revenue and the need to borrow capital will

be reduced. This minimizes capital investment and where assets are available it may allow alternative investment opportunities to be explored that will diversify and strengthen the airline's portfolio. Thus, if an aircraft is leased, the following benefits should accrue:

- On an annual basis, provided the leasing agreement is long-term, the lease option is the cheaper alternative.
- The annual repayment cost (and the same is true whether a lease or a purchase agreement struck) diminishes as the repayment period increases.

The main benefit that accrues if a fleet is purchased rather than leased is that there will be an asset on the balance sheet. This adds value to the firm, but it is an inflexible asset, and that might not be a great advantage. Leasing does offer the chance, therefore, of reducing operating cost, only slightly, but perhaps crucially, because it can impact the airline finances appreciably. One reason why a leasing company can provide aircraft at relatively favorable terms is that they will bid for a larger quantity of production slots than most airlines and thus have a special relationship with the aircraft manufacturer. They will often agree to take _spare' slots between promised deliveries, and on both counts they are able to negotiate a discount from the builder. Nevertheless, some airlines, and especially the newer breed of low-cost carriers that have single-aircraft type fleets, can buy from the builder in bulk, and if they approach the manufacturer at the right time (with regard to their own costs) they will be able to negotiate a similar discount. Large airlines sometimes lease part of a fleet and buy the remaining aircraft, so retaining a degree of ownership and incorporating some flexibility. In reality, leasing and purchase deals can have many more complex characteristics. Although the actual prices of aircraft are published regularly in some journals, the acknowledged price is likely to represent the highest price that any client would have to pay. Having now explored the synergies that link the aircraft manufacturer and the operator, the scope for flexibility is much clearer.

Revenue generation

After costs, comes revenue. Fares are not the sole source of revenue for an airline, but this is the most significant income source. The commercial specialists in an airline coordinate with route and fleet planners, determining the pattern of frequency of service, seats configuration, the impact of a lease/ purchase deal, etc. Based on the costs they can attribute to these decisions, they declare a yield target for each service. Yield is the amount of income that is necessary to cover costs per seat available. Hence, if there are 100 seats available and 75 are sold at £40 each, the income is £3000 and the yield is £30 (per seat available). If the yield target was over £30 this would be a loss-making route, but if it was below £30 it would be a profitable service. Yield management – the tailoring of fares to ensure that yield targets are exceeded on as many services as possible – plays a large part in determining what fares the airline will charge. The general belief is that the lower the price of a ticket for a given service, the more passengers will be attracted. If the operation is between two locations with well - developed economies, there is likely to be sufficient disposable income for that expectation to be true. However, in less well-developed economies, the availability of seats is irrelevant if the population does not have the disposable income to spend on travel. In the latter case, no matter what fare is set, the aircraft will fly almost empty.

Even in situations where demand is buoyant, eventually demand will saturate. If the service is between two small communities, there will be a limit to the frequency of service that can be operated with a given aircraft type, but the smaller the aircraft the higher the frequency of service that can be

economically sustained. This is all based on the idea that seats are sold at a single price, which is a great simplification, because airline marketing strategy is usually based on offering seats at a range of prices. For example: A low-cost carrier might demand that a late-booking passenger pays over ten times the price for a seat as the early-booking passenger. . On a traditional' carrier, as has been hinted already, the cabin might be divided into compartments (on long-haul operations, first, business and economy cabins are commonplace), and the price of the seats, while again not immune from a time-before-flight variation formula, will reflect the relative quality of service offered in each cabin compartment. Access to seats at two different fares will always favor the lower fare, so low fares are usually released early in the booking period (which might commence several months before a flight is due to be operated) and the price will increase as the date of operation approaches. This is generally true, but not universally applicable, as where a carrier has a desire to pull market share and has little regard for profit – more an interest in beating the competition into submission – fares may even fall, provided seats are available. This is a risky and relatively rare strategy, but it is an example of financial viability being more important than profit alone. If a competitor will split the market and limit the ability to make a commercial success, then if there is a belief that the competitor is less able to sustain a period of losses, an airline may choose to operate below its own margins.

Computerized reservation systems

IARE

The flexibility that is associated with fares in aviation was not always there. In the 1950s and 1960s there was a tendency for all airlines that offered licensed air services to be members of the International Air Transport Association (IATA), and it was IATA that set the fares. A few companies, often referred to as independent airlines, operated outside of this regime, but they accounted for a minute proportion of all operations and they were unable to enter into cross-carrier booking. Two IATA-member airlines could share a fare from A to B via C, where the two carriers flew A to B and B to C on their respective route networks, but where no one offered A to C direct. This was called prorata fare setting and is still in place today. The process is often called clearance, and the airline personnel who handle the process are the revenue-accounting department.

Fare structures came in for a major overhaul, however, when computerized reservation systems (CRS) were introduced by the major airlines in the late 1960s. Initially it was based on the airline's own needs, and the way it could be accessed was two-fold. A customer could enter a local shop (the airlines had their own booking offices in all major towns) and book a ticket through the airline clerk or telephone an enquiry. As investment in CRS began to grow, airline offices disappeared, as they were expensive to run. Now all the airline clerks were concentrated into what we would regard as a _ccall-center' today, and they would process requests from customers or travel agents by telephone. If the enquirer was a travel agent, they could book a ticket for a client and they took a commission. In addition to changing the customer interface, the most significant operational influence of the CRS was the way it allowed seat sales to be monitored. It was a long overdue advance for airline sales staff, who had long yearned to be able to _manage' seat sales. They desired not just to offer seats and have happy passengers, but to ensure that all seats would be sold – on an individual flight-by-flight basis – and, crucially, at the highest price that people would pay for them. This was the beginning of the yield management' process.

Initially a variety of ticket options were used, introducing terms that have characterized the changes that were occurring within the business. These included:

- Advanced-purchase excursion (Apex) tickets. Basically, this was to buy well in advance and get an economy ticket at discount. Airlines put very tight controls on ticket validity, but this still appealed to those on long haul flights visiting friends and relations (VFR passengers).
- Business class. The full economy fare passengers objected to having discount passengers on the same seat rows, so the airlines introduced a better quality service. Modern business class equates to the old-time economy modern economy is a lesser quality product (in terms of ticket validity). Later, better seating (greater width and pitch) became the norm for business class.

AIR TRANSPORTATION SYSTEMS	
Source from Air Transportation Systems by M	ike Hirst

In the 1970s, the number of fare categories applicable on a long-haul flight grew rapidly, from a basic two (with some variations) to in excess of 20. As the decade wore on, the short-haul flight scene changed equivalently. An associated initiative was the frequent flier programme (FFP). This was a simple way of giving recognition to a loyal customer. The customer's FFP membership card helps airport counter staff to recognize passengers whom they should regard as commercially more important than others (cards are banded as silver, gold and platinum). Alternatively, or additionally, by accumulating _air miles' the customer gets a bonus that is once again recognition of their loyalty. Some air mile' schemes extend into the wider retail market and can be accumulated in non-aviation activities. By the mid-1980s there was a particularly serious operational complaint, which was that the CRS was often _biased'. The oft-quoted case was that if a customer used a travel agent, who officially was _unbiased', to research flights between A and B, the probability of a booking being made that was not in the top six listed (typically the first screen listing) was very low, so the airline that was providing a CRS service would thus put its own services at the top of the list in its own system and win an unfair advantage. As not all airlines could afford a CRS, the larger airlines offered access to travel agents via their own CRS, and they were in a powerful position to monopolize demand on the busiest routes. IATA, acting as an independent body, worked with anti-trust law enforcement agencies to generate rules that were fairer to the customer', and these apply to all CRS software programs. However, the airlines have a neat side door: they often get their flights quoted many times through having code-shared flight numbers. This is also regulated as tightly as it needs to be, again to maximize the public's ability to get good value for money. In general, on a modern CRS flights will be displayed according to best times (using user-declared criteria) and then lowest fares, and only then is the airline taken into account.

The most significant recent development in this field has been internet linking, allowing customers direct access to the CRS from their own home, or at any time and anywhere if they have an appropriate terminal with an internet link. However, since the mid-1980s the presence of CRS has not been the most important issue, insofar as software-based processes have evolved on the back of the databases with the system. These are _yield management' systems. Their underlying principles deserve study as they probably share characteristics with many future business developments. As they aim to be _fair' to passengers, they have to acknowledge that they are a business instrument that theairline is also using to enhance its own competitiveness.

Fare (\$)	Seats sold
0	100
20	100
40	100
60	100
80	100
100	100
120	80
140	62
160	46
180	32
200	20
220	10
240	5
260	2
280	0

Table 6.4 Hypothetical fare and seats demand relationship

AIR TRANSPORTATION SYSTEMS Source from Air Transportation Systems by Mike Hirst

Yield management

For every route there will be a yield target, which has been determined from the airline's operating philosophy, choice of aircraft type, fleet size and utilization, and the many other influencing issues. Yield managers must attract rather than deter customers, so they try to maximize load factor. However, they must expect to be mandated to ensure there is the flexibility to accommodate highyield as well as low-yield customers, although the former are risky in terms of their propensity to book late and even not show for a flight. These are difficult objectives to reconcile. Consider a hypothetical service operated by a 100-seat aircraft, where, with a single fare, the prognosis is that demand will follow the fare, as shown in Table 6.4. A zero fare operation might fill the aircraft, but revenue would be zero. Likewise, if the fare was very high, \$280 shown, the situation is the same in terms of revenue because the demand is now zero. Somewhere in between is either a better solution or a range of better solutions, and the yield manager is expected to identify and keep that range and keep route sales performance in an acceptable band. In the example described, the revenue, load factor and yield values that emerge from the anticipated demand are shown in Table 6.5. If an operating cost assessment has set a yield target of \$40, there are two limiting solutions. Selling all seats at \$40 each promises to recover costs. Alternatively, at about \$205, while only 19% or so seats are sold, the same yield target is achieved. Anything in between is likely to prove to be a profitable operation. In such a case the yield manager can be expected to release seats

Fare (\$)	Load factor	Revenue (\$×1000)	Yield (\$/seat average)
0	100	0	0
20	100	2.0	20
40	100	4.0	40
60	100	6.0	60
80	100	8.0	80
100	100	10.0	100
120	80	9.6	96
140	62	8.68	86.8
160	46	7.36	73.6
180	32	5.76	57.6
200	20	4.4	44.0
220	10	2.2	22.0
240	5	1.2	12.0
260	2	0.52	5.20
280	0	0	0

Table 5.5 Demand relationship viewed as revenue and yield data

Table 5.6	Yield	manager's	fare and	sales	allocation
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	Fare (\$)	Allocated seats	Seats sold	Revenue (\$)
	10	10	10	100
	20	15	15	300
	40	20	20	800
	60	20	20	1200
	80	10	8	640
	100	10	6	600
	150	10	5	750
	200	5	3	600
Total		100	87	4990

gradually, starting with low fares, and letting the fare rise progressively, so long as demand is not receding. When the latter happens, if there are still seats to be filled, the fare will drop again. For the hypothetical service already considered, if the yield manager allocates seats as shown in Table 6.6 and sells seats in the quantities shown, the revenue shown is generated. This is a solution where 87 seats are filled (so load factor is 87%), where the revenue is \$49.9 per seat, handsomely exceeding the \$40 per seat yield target, 45 passengers paid below or at the operating cost per seat and 42 passengers paid more than the cost. This example is not untypical of the solution that is applied in many modern short-to-medium haul operations.

However, every flight is different. What happens between A and B at one time of the day might not be

the same as what happens at a different time, on the same day or at a different time of the year, and so on. It is the yield manager's responsibility to release seats according to a price strategy that will also distribute passengers across the less-favored flight. The principles have now been stated, but in reality the quest for business in the commercial market can be much more demanding than the example suggests. The most demanding aspect of passengers who pay a _full fare' is that the terms of the ticket give them the right to change their booking whenever it suits. They can be booked on a flight, be detained on business and miss the flight, and then arrive at the airport and request a seat on a later flight. It is a right they have purchased. They are a _no-show' on one flight and a _go-show' on another. If business has taken an unexpected turn, they can decide to fly elsewhere and then return via a different route, securing new tickets. To accommodate their discretion and to ensure that load factors do not tumble as a consequence, an airline can _overbook' passengers, meaning that they will issue a total number of tickets that exceeds the number of seats on the aircraft. Statistically, they will expect the demand to redistribute itself such that the chances of a passenger being stranded are acceptably small. This is policy and the resolution of overbooking is an operations issue.

The effort needed to conduct yield management is considerable, and in a large European airline with 100 or so aircraft, flying long-haul and short haul, there can be 400 flights per day or close to 150 000 flights available at any one time on a one-year-ahead booking system. The yield manager uses the CRS infrastructure to look under the surface for unusual sales profiles and to draw attention to where decisions need to be made.

Integrating service quality into the revenue generation Process

The dichotomy that vexes the astute manager's mind is that _overbooking' to protect against _noshow' and _go-show' eventualities is tantamount to taking risk with customers. The yield management description has shown that these are often late-booking travelers, which means that they are the people that the airline depends on to make a profit, and thus if they do not roll up the service runs only marginally, in financial terms, and may be even at a loss. The airline has to be _kind' but cannot afford to foot the bill. The way this is handled in planning is to appreciate that the average load factor is just that – an average over a number of events. On 50% of occasions the load will be higher. If the average load factor is 60%, the chances of a load reaching 100% is less likely than if the average passenger load factor was 70 or 80%. A technique is needed that will determine what proportion of passengers are likely to be turned away, either on enquiry or at the gate. One technique that provides some useful insights into equivalent service quality related issues that have yet to emerge is a technique called _spill factor' analysis.

Spill factor (an analysis technique developed by Boeing in the 1960s) assumes a statistical distribution of demand and presents a relationship between the average load factor and the probability of having a load factor that is above or below this value. It is suited to assessing the likelihood of a 100% load factor, and thus is a means by which capacity limitations can be related to service quality issues. The technique is as follows. To measure _spill' it is necessary to derive, or predict,

the mean passenger load (m)

the standard deviation (s)

the coefficient of variation (k)

k = s / m

The kind of issues that have to be tracked to understand 'why demand varies are quoted to include:

seasonal (winter/summer) daily (weekdays/weekends) time of day

holiday (can be seasonal related, but especially peaky ').

Boeing comment that demand will be different in different directions, so A to B is not the same as B to A. Their analysis also suggested that 0.2 < k < 0.4 for airline routes (but that might not be so true 40 years down the line) and that route passenger data can be analyzed assuming the distribution of passenger loads as a Normal distribution. Statistical theory suggests that, because passenger numbers are discrete and cannot have a negative value, this must be wrong; the distribution should be binomial or Poisson. However, it can be shown that in certain ranges of values of mean and standard deviation, the normal, Poisson and binomial distributions become very similar. This is true for most airline passenger load applications unless the aircraft is very small. It is recommended that when analyzing operations with a 40-seat size aircraft and smaller, analysis should assume a binomial distribution. Spill factor theory suggests that if the aircraft capacity (maximum number of passengers/flight) is C, the expected load can be expressed in the following way:

Expected load = $(m _C) F0 [(C_m)/s]_s f0 [(C_m)/s] bC$

where fO(x) and FO(x) are expressions from normal distribution probability

Table 6.7 Example of spill evaluation

Passengers spilled	Expected load	С
5.58	44.42	50
2.73	47.27	57
1.17	48.83	64
0.41	49.59	71
0.12	49.88	78

tables. FO(x) is the accumulated area across the distribution and fO(x) is the normalized value in the distribution.

Example

m = 50 passengers/flight, s = 14 passengers/flight, hence k = 0.28 If C = 78 (maximum number of passengers/flight)

Expected load = (50_78) F0 $[(78_50)/14]_14f0$ $[(78_50)/14]b78 = 28 F0(2.0)_14f0 (2.0)b78$

=_28 (0.9773)_14 (0.0540)b78

=_27.3644_0.756þ78

= 49.88 passengers/flight

Passengers lost (or spilled') = 50_49.88 = 0.12 passengers/flight

If this evaluation is conducted for several capacities, a pattern emerges that seems logical but would be difficult to justify otherwise (see Table 6.7).

Hence, a logical conclusion is shown, that increasing capacity reduces the possibility of spilled passengers on any service. It is also possible to use passenger spill data to estimate the cost/revenue benefits for an airline. The example in Table 6.8 assumes that the loss of one spilled passenger is \$200 (route fare) and the extra operating cost of one added seat is \$50.1 From the above analysis it can be concluded that:

It is well worth adding 7 extra seats to the available capacity.

It is not worth adding 14 or more seats.

The value of spill analysis is clear when it is used to estimate the spilled passengers per flightand to look at it as a proportion of passengers boarded.

 Table 6.8 Spill evaluation results

Capacity	50	57	64	71	78
Capacity cost (base)	\$350	\$700	\$1050	\$1400	\$1750
Incremental cost	(\$350)	(\$350)) (\$3	50) (\$3	(50)
Spilled passengers	5.58	2.73	1.17	0.41	0.12
Incremental spill	2.85	1.56	0.76	6 0.2	9
Incremental revenue gain	\$570	\$312	\$15	2 \$58	В
Revenue gain less cost	+ \$220) -\$3	8 -\$	198 - 9	\$292

If the proportion of spilled passengers exceeds 5% of the aircraft seat capacity, the possibility of a passenger being refused a seat (not boarding) will be greater than once in every 20 enquiries. This can be treated as a threshold that will cause business users to look at competitor's operations. By using theanalysis in this way, an assessment can be made of whether the trade-off in getting a high load factor with improved revenue (short-term benefit) will lead to disappointment among passengers (long-term dis-benefit), leading to a hemorrhaging of demand in due course. It is the application of a process of this nature that leads analysts to assume the load factor pattern shown when a three-class cabin was analyzed earlier in the chapter (which assumed an 85% load factor in economy, 65% load factor in business and 45% load factor in first class). The chances of a late-booking first-class passenger being refused a seat or of ever being overbooked are negligible. It is privilege, however, that comes with a sizeable price tag.

Marketing the seats

The concern in these notes is largely in planning as the mechanisms that will be used to sell seats (marketing) are not deeply considered. The airline will pursue a policy in ascribing service quality criteria at the planning stage that will reflect the way they will market the products, or airline _brand'. Demand can be tailored by successful marketing policy, and in yield management the impact of marketing initiatives can be monitored. Thus, real-time tactics can be used to fine-tune the revenue-generation process. There is no reason why, within the limits that a mature use of the capacity variations that a good revenue-generation policy offers, a success cannot be extended, or enhanced, or a failure militated against. This is a concern that affects how a company manages the sale of a perishable commodity. This situation, and a process for managing it, will re emerge in later chapters. It is difficult to overstress how important an example this is in terms of the way it can be read across to other service providers in the aviation business, whose contribution is yet to be considered.

Airline scheduling

The scheduling process is where many of the implications that stem from the earlier work come together. The scheduler must ensure that each aircraft is allocated to perform the services planned. The information needed is:

- a. routes to be served
- b. time-zone of each destination relative to the hub
- c. number of flights/weeks per route
- d. block time on each route
- e. Number of aircraft in fleet.

The scheduler allocates each aircraft to each service, taking into account:

- 1. Turn round time: the minimum time needed to empty and refill an aircraft when it passes through an airport
- 2. where aircraft will be overnight, as not all will necessarily be at the hub on every night of the week
- 3. the time of the day when passengers will want to fly.

The turnaround time is governed by logistical and aircraft servicing needs.

Therefore, the longer the preceding flight, the more likely it is that the aircraft will need more time to refuel, to clear rubbish from the cabin, to restock the galleys, etc. The agreement for a given turn round time might also hinge on some airport policy issues, with fast turn round bringing substantial

benefits when it comes to agreeing airport charges. This is a negotiable issue and has become a valuable bartering chip in some airline/airport agreements.

The choice as regards whether an aircraft conducts an overnight stay at an outstation can hinge on passenger demand and time- zone influences. Where a route structure has a considerable east-west dimension, the best operating plan is to start aircraft at the east as the sun rises and to travel, almost keeping with the rising sun in high latitudes, in order to land at an early local arrival time. It does not work _both ways' - heading east it is necessary to do it in daytime or if the flight has a long duration (typically, in excess of six hours) to do it overnight. If a route does not have a high service frequency (in excess of 28 flights per week) the choices can be stark; if a daily schedule is to be created there are only two flights daily in each direction to plan. The passenger attraction of certain times of the day is less likely to be as influential when a more frequent service is provided. These are issues that might lead to re-evaluation of the aircraft size/service frequency trade-offs introduced by the fleet planner.

There are no hard and fast rules as to what times of arrival and departure are likely to win the seal of approval of passengers. An oft-used illustration in textbooks shows two humps on a 24-hour time plot, and suggests that there will be a preference for flights in the early morning (for people flying _out') and in the evening (for people _returning'). This is true in business operations over a limited number of time zones, for example in the US _corridors' (Boston–New York–Washington and San Francisco– Los Angeles–San Diego) and across most of Western Europe. It is not so true of US transcontinental flights or for long-haul flights, such as between Europe–North America and Europe–SE Asia.

Figure 6.5 was derived from an analysis of timetables in the mid-1980s. With the assumption that combinations of flight departure and arrival times (local at the departure and destination points) illustrate what airlines have found can equate to attractive schedules, it can be treated as a passenger attractiveness plot. The outcome is essentially only true for business demand, as leisure (charter) and no-frills carrier demand characteristics are not so pronounced, although they do have to take account of diurnal demand patterns. (A proposal is that the pattern still exists, with less pronounced valleys and peaks, but this has neither been investigated nor validated at this point in time.) As aircraft are allocated to routes a set of aircraft schedules will emerge, and the departure and arrival times have a degree of justification. The daily aircraft schedule for a small fleet can be generated readily, but for a large

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Time of service and passenger attractiveness.



A hypothetical airline schedule: four aircraft serving four destinations from a hub. fleet the task can take a considerable amount of time. Computers can take some of the guesswork out of scheduling, but almost all airline schedulers perform adjustments to computer-generated flight times before they submit flight numbers and times for incorporation in the airline's timetable and CRS database. Some of the issues that human interference adjusts for are:

- 1. early departures, and distributing aircraft in _departure waves' late arrivals, and distributing arrivals in _arrivals waves'
- 2. introducing the chance for aircraft to switch schedules, or built-in _robustness'
- 3. ensuring that aircraft at the end of a day are where they start the next day.

Evaluating success

Having navigated through an airline planning process that has considered route planning, fleet planning, yield management and fleet scheduling, the chapter arrives at the point where, although all the participants in the process should be able to justify their contributions, no one has yet looked at the consequences against criteria that will relate to the objectives of the airline itself. In particular, by now there should be enough evidence to be able to measure the airline's likely performance against the criteria set by the principles that have been supposed. Financial viability This can be assessed in the simplest possible way by comparing revenue and expenditure over a given period of time. It is comforting if revenue exceeds expenditure; the difference is profit, before tax and any other hidden expenditures are taken into account. The most common expression of financial performance associated with this viewpoint is the profit/loss statement. Most airlines will supply to their economic regulators (and thus make public) a monthly profit/loss statement, which may be published several months in arrears, but which can be drawn together over a 12-month period to present an annual account. These data are sometimes produced in specialist aviation press magazines and provide evidence of issues that affect the daily operation of airlines. They will show, for instance, . seasonal variations, which might be most pronounced on _regional' airlines

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Source from Air Trans	portation S	ystems b	y Mike Hirst

- o public/bank holiday variations, which might coincide with religious festivals
- global influences, a downturn in economic performance, a natural or other disaster, and similar events.

Of these, seasonal and holiday effects can be predicted and there will be detailed planning to cover their occurrences. The implementation of service variations at this level of detail is closely aligned to airline operations. Global influences are external and are the kind of events that can test the financial robustness of airline plans. Some analysts look at the ratio of revenue to expenditure (revex ratio) to judge overall viability. A revex of 100 is when revenue and expenditure are equal, and for a revex of 110 the revenue exceeds expenditure by 10%. A 10% excess of expenditure over revenue is a revex

ratio of 90. A review of most airlines accounts, as published annually by organizations such as IATA, shows that the revex of large airlines is generally around 105 to 110, with some years below 100, and a cyclical variation over several years; in some periods it has seemed to be a seven-year cycle. The average revex is about 104, suggesting that roughly 4% of revenue overall is profit. This sounds small, but on a \$10 billion annual turnover this is, nevertheless, a \$400 million annual profit. In perspective, it is equivalent to the revenue from a two-week period. Airlines do not always run at a profit. Winter slumps can cause an airline to be __in the red' for a number of months every year and then financially buoyant over the summer, making for a decent average over the year. Airlines are loathe to see any decisions taken that will affect what they perceive as a very fragile __bottom line', which is all too common in this era of passenger and movement levies, whether justified on security or environmental grounds

Note that revex is usually measured after all expenses have been taken into account, so the profit will be after tax and shareholder dividends have been paid, for example. The straight trading profit' can be hidden and might be substantially greater than published accounts will show. A long-term investor, such as a leasing company that is arranging the financing of a fleet of aircraft, will want to delve much deeper and will look into the instantaneous value of the debt/equity ratio, at long-term borrowing and at the trend in such measurements of financial performance. This can mean that for substantial periods the airline, in addressing future development through route development or fleet acquisition, might choose to operate unprofitably. If they have a forecast of the way that profitability will be affected by plans and they present evidence that they are managing the process successfully, this will count towards good viability. Airlines often sit on large amounts of cash, paid by customers in advance of flights. In most well-regulated countries these funds cannot be regarded as an asset. They are held as a bond, which might be used as security against borrowing, providing that the risk is underwritten on the insurance market. If the airline does have to cease trading, the bond should ensure there is money to pay for the recovery of stranded passengers, as without such protection they would be simply a creditor and would be queuing with service suppliers, aircraft leasing companies and banks. They are assured of some protection.

Regulatory compliance

Compliance has many facets, and economic regulatory compliance is already evident in the way that financial viability has been described. There is much more, however. Safety compliance is largely an airline operation responsibility. The airline will have a licence and some of the named staff requirements and operating region limitations this will entail have been described. The named staff will have a responsibility to ensure compliance with crew flight-time limitations (FTLs), mandatory training requirements, an aircraft certificate of airworthiness and maintenance compliance, and other statutory articles. This is not so one-sided as it might seem, and in most well-run airlines the senior

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staff and the regulators will be well known to one another and will have times when they meet to solve issues that arise. Regulators also analyze mandatory occurrence reports (MORs), and in some countries they will be given access to databases that are run by organizations that do not have a regulatory mandate (the confidential human incident reporting procedure (CHIRP) system in the UK is an example). If they believe there is a trend that deserves debate – it might be a series of unrelated events that they construe to suggest that non-mandatory training of some staff is not proceeding at the level necessary to maintain an adequate safety standard – they are empowered to open a debate in order to look for an agreed plan of action and to monitor progress against objectives. A good safety regulator will seek to solve issues in this manner rather than wait for serious incidents and then to invoke their most powerful mandate, of revoking the license of an individual, a group of individuals or an organization. On the aircraft itself safety is the responsibility of the crew, and it is clearly the responsibility of the flight crew to fly the aircraft according to safe procedures and to handle unscheduled events with minimum effect on levels of safety. The cabin crew are there, first of all, for safety compliance. They are trained to handle emergencies, so it is no coincidence that they sit by the main doors at take-off and landing.

Security compliance is usually a national responsibility, although there will be international facets to the work too. The airline will have a responsibility to vet all passengers, goods, baggage and other articles carried as payload, which they might subcontract but nevertheless for which they will be held responsible.

Environmental compliance has been a growing feature of aviation operations, affecting airlines and airports in particular for some 40 years. The turbojet airliners of the 1960s were intrusively noisy and were so frequent at busy airports that they constituted a real noise nuisance and could be predicted to become a serious threat to health – physically and mentality. There has been respite, with turbo-fan engines – admittedly introduced because they are more efficient than turbojets – using slower moving air mass and creating diminished noise. There was a profound reduction in noise levels while aircraft size increased in the 1970s, and there has been a steady diminution of noise nuisance per operation as every new type has been introduced ever since. There are noise certification regulations that an aircraft must pass during development, and failure to meet statutory noise levels (measured under the approach, sideline and under the climb out) can lead to certification being refused.

Noise has also become synonymous with air pollution. The larger aircraft do burn more fuel, but the fact that it is less per passenger than hitherto is no longer regarded as an adequate argument. The air quality in the wake of aircraft, measured in terms of hydrocarbon and more noxious gas emissions, is being increasingly regulated. The airlines and airports share the burden of creating operational solutions that meet local needs, as well as being compliant with regulatory accords. The room for flexibility on these issues is reducing year-on-year, and the way that environmental compliance will affect operation is so clearly grave that aircraft designers are having to reconsider the design of their airframes, the way they install and operate engines, and so on. The solution to the dilemmas faced by the industry overall will be one of the major issues debated in the future, and thus is accorded greater coverage in later chapters of this book.

Efficient use of resources

This is not a stand-alone topic, in that it has been alluded to in both preceding sections. The efficiency of an operation is measured crudely by some statistics. Aircraft annual utilization is one, with most airlines nowadays trying to get several thousands of flying hours per year from each of their aircraft. Some of the pros and cons of aiming too high or two low have been discussed in this chapter, and similar attribution given to the way that safety -critical items and personnel are employed. An airline will audit the utilization of such facilities as the maintenance hangars, flight training simulators, specialist ramp equipment, and even the baggage bins and galley carts. A simple spot check on

efficiency in an airline is to assess the number of crews per aircraft, irrespective of the annual utilizations posted. A very unreliable measure is the number of employees per aircraft, or per passenger, or even passenger -km. The problem when such wide ranging statistics are developed is that they may mask a tendency to outsource (which makes the data look good) or to do work with inhouse employees. The latter might even be outsourced for a proportion of their time (say, handling other airline's flights between the periods when they handle their own), so productivity might be higher than it appears to be. Provided an airline takes care to utilize people as well as equipment, the efficiency aspect of the business should be in balance with the other issues that need to be considered. The human resource department should be able to assist a manager to remain aware of people's skills, ambitions and attainments. The fact that people do a good job does not mean that they should be left there. They might aspire to quite different work. Opportunities should be recognized and people guided rather than managers having to wait until appraisals throw up expressions of dissatisfaction. The balancing of people's aspiration with organizational needs and aspirations is often the most significant contributor to efficiency in a workforce. The path is easiest with young employees, whose skill base is still maturing and whose curiosity often makes then inquisitive to move from post to post.

As people get older the temptation to stream those suited to management 'to those who are more hands-on' is often the most critical and poorly handled issue of all. However, in an airline, where the business might occasionally slump, but where growth is almost assured, the opportunity to build the business and people in harmony is perhaps easier than in almost any other business.

Effective service

In the context considered here, effective service is about the attainment of corporate goals that focus on customer satisfaction. A passenger will be attracted back to an airline whose service has suited their needs, and while the attainment of satisfaction over all categories of passengers is desirable, it is expensive to achieve. Airlines that desire such wide success, as has been discussed above, regularly have three-class cabins to attempt that, but some airlines use just one-seat configuration and tailor demand, capacity, time and price as carefully as possible to get what they see as effective use of resources, and believe they can judge the customer service qualities accordingly.

Service quality is the leading issue in effectiveness but measuring it is an art that has yet to develop the finesse of science – arguably that will never occur. A passenger will appreciate the quality of a seat of greater width, or with extra pitch between seat rows, and they will attribute qualities to the availability of in-seat entertainment, good food and drinks service, and so on. There is a lot to be said for trying to measure what passengers like and dislike, and the latter can be the catalysts that will allow others to contribute towards solutions.

An airline that said it was finding long-haul passengers disliked seats by the lavatories on aircraft because of the disturbance caused by users, the high probability of a queue at the end of a flight and the occasional smell from chemical toilets took its views to an aircraft manufacturer. They reasoned that on the longest-haul operations the belly holds were only partially filled with baggage and little freight, and so they devised an innovative stairway into the hold from the cabin that replaced the space that would be occupied by an on-deck toilet. Below the cabin they could create a queue space and a number of washrooms. The design improved access to toilets, lessening queue length, removed the queue from nearby seats and ensured that any noxious smells were banished from the seated passengers. This is a clear example of getting a requirement expressed in the right terms (customer service led and not just efficiency in a technical sense) and getting a solution that one element of thesystem delivers to another element. An issue that is making designers challenge their efficiency criteria at the current time is the _dissatisfaction' that people express when, having become

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accustomed to the two-aisle configuration of a _wide-body' type, they are thrown into a single-aisle _narrow-body' aircraft. The addition of a second aisle, in excess of 50 cm wide, to a six-seat per rowaircraft, which has an external diameter of perhaps 3.5, increases the frontal area by some 30%, which can have a considerable impact on aircraft drag, and thus every efficiency indicator. Designers will not sacrifice such efficiency for the effectiveness that the airline will say it can sell, given that the passenger will have to pay an increased ticket price to cover extra operating costs. If the increasedfrontal area was perhaps half this value, 15%, the fuselage could be increased by some 0.3 m. Would a _wide-aisle' aircraft with some 80 cm between opposing seat rows appeal? If the passenger couldsqueeze past a galley trolley (that is not necessarily a good criteria) it might be regarded as a good improvement. However, here is an example of the ways that commercial entities (airlines) caninfluence the decision-takers in the technical providers (the aircraft builders). Making the decision to go _wide-aisle', if anyone ever does it, will be a prime example of balancing the quest for commercialreality with technical feasibility.

The previous paragraph has established that there are ways in which two of the four elements of the air transport system considered here can be linked, and it is easy to surmise that this is just one of a number of possible links. More will be established and explored, because it is firmly the case that this is where progress will be most attainable in the future, giving cooperative rather than isolationist existences. The next two chapters drive deeper into this newly emerging world of exciting and far-reaching opportunities.

UNIT-V

AIRSPACE

Abstract: This chapter looks at airspace management systems, through perspectives that help to draw parallels with those that have been used in the aircraft, airline and airport chapters of the book. Airspace demand and capacity situations are among the most critical of the problems that must be solved if the air transport industry is to continue to function efficiently and effectively. Such linkage has been generally too piecemeal, or elusive, using more single discipline based analysis. The intention is to describe airspace issues in terms that relate to the situations that require consideration, and compromise, elsewhere in the air transport system.

Key words: categories of airspace, separation standards, airspace sectors, demand, capacity and delay relationships, functional evolution of ATC systems.

Introduction

Most aviation professionals fail to consider _airspace management 'in the same breath as the rest of aviation. The excuse is not one of disrespect but because it is a ground-based, and thus almost invisible, component of the air transport system. Originally it was called air traffic control (ATC), and ATC is still the preferred term about the work that is conducted from airport control towers. This occupies a cab, atop the highest of an airport 's buildings, and also requires an approach'unit. This is usually a room where radar screens glow and where much of the strategic and tactical work that complements the activities in the control tower is conducted. ATC is more than that, and in the 1980s the phrase airspace management 'was coined to cover the breadth of activities conducted at airports and in often unseen air traffic control centers (ATCCs) throughout the world. ATC service providers have always had a high proportion of their staff located at ATCCs, and although these usually started life in buildings on the periphery of airports, nowadays they have often moved into parkland or on to an anonymous plot within a city industrial estate. ATC was set up as, and remains, a service industry. Its mandate is to utilize and police the skies, ensuring (according to the original and long-held mantra of the business) safe, orderly and expeditious flow of traffic '. In its early days, in the 1930s, it was never considered necessary to add the word capacity 'to that description. The skies were regarded as a vast three-dimensional ocean in which aero planes could fly. An individual aircraft seemed insignificant in this enormous cavern, and the job was not to impede but to control 'access to the sky and to assure flyers that they would be provided a separation service that would eliminate the risk of mid-air collision. The control element relied upon rules that would uphold the profession 's objectives, and these were formalized during the 1940s in ICAO Annex 11 (Air Traffic Services).

Solving the conundrums of the increasingly capacity-strapped en route airspace depends on more information, and thus more sophisticated sensors. As information flows in ever-greater volumes, the digital computer is used to help to digest and present that information with reduced ambiguity. The computer is a decision- support tool. Over time, circumstances have driven this role deeper, and now it threatens to reach into the decision-making regime. The implications, in terms of capacity and safety, and indeed the whole balance of power in the decision-making chain throughout the air transport system, are enormous. Purists might deplore it, but the route that has been followed, and seems sure to be followed, leaves little

doubt about the significance of the changes that are about to take place. The questions that are difficult to answer are those that determine at what speed this change will occur.

Meanwhile, the humble airport-based ATC unit has seen plenty of change in the same era, but nothing is ever likely to change here to the extent that it will in ATCCs. In this chapter the way that ATC has evolved into the so-called air -navigation service provider (ANSP) network will be charged with an eye on each of the four objectives that previous chapters have drawn out from analysis of how aircraft are manufactured, and how airlines and airports are planned and operated. This is because ANSPs also have to be financially viable, to be compliant with international statutes (and more than any other part of the business, the air traffic profession is watching the statutory scene change almost more rapidly than they can react), to be efficient and to offer that effective (expeditious) level of service that has been central to its belief system from the earliest days. By the chapter end, the four main components of the air transport system will have been described in equivalent terms. The remaining chapters of the book will be able to look at the symbiosis between these components of the system. Setting up an airnavigation service provider Business Initially air traffic control was a public service. In the 1930s and 1940s nations did not look upon ATC as a, potentially, commercially viable business. The service was set up on a national basis to exercise control over the airspace in which the operator nation has been ceded sovereignty '. How the limits of this airspace were defined was, and remains, a semi-political task. The need for redrafting of boundaries is not day-to-day work, but it is necessary when a nation subdivides, as has happened many times in the 20 years or so since the Soviet Union and neighboring nations took independence. Within the airspace, which is controlled 'with regard to all air-breathing vehicles (officially up to an indefinite altitude, but clearly not extending into the vacuum of space), there are categories of airspace that are defined in terms of the service quality that is provided within them. There are seven categories defined in ICAO Annex 11, characterized as A through to G, with the highest level of service offered in Category A and the most basic service in Category G.

Categories of airspace

The subtle division of different segments within which aircraft are provided with different levels of service, while easy to draw on a map, are difficult to distinguish. Navigating routes was initially a task performed using radio navigation aids, and these were sited and used in such a way that they aided aircraft to maintain a position within the sections of airspace allocated to them. Hence the shape of airspace 'was linked directly to radio navigation aid location and performance, and the navigation aids (nowadays usually VORs with co-located DME – see Chapter 4 on the operational environment for a description of this and other navigation aids) have become the _reporting points' through which flow has been monitored and controlled by ATC staff. Airways are the routes, akin to aerial highways, along which airlines fly when cruising and during the higher-level stages of climb and descent. In most cases they are 10 nautical mile wide and aim straight between radio beacons. The base 'of an airway is always 1000 ft or more above terrain and rarely below 5000 ft above mean sea level, and extends up to 25 000 ft, and may even extend higher. These general rules allow space beneath airways in which aircraft can roam freely (and accept that a collision risk is present), thus allowing noncommercial aircraft to fly for pleasure. They usually accept responsibility for collision avoidance by flying under visual flight rules '(VFR), meaning that they fly during the day and stay clear of clouds. Within the controlled airspace commercial aircraft assume instrument flight



Categories of airspace.

rules'(IFR), meaning that they will operate day or night and in any visibility conditions. This isimportant if airlines are to publish and maintain regularly timetabled services. When aircraft are climbing or descending close to major airports, they are within a terminal maneuvering area (TMA), or similarly designated block of airspace. In plain view this is often very irregularly shaped, and its vertical extent can vary with location, with no fixed upper limit, although 15 000–20 000 ft is typical. The TMA base is lower than the airways, but still at least 1000 ft above the terrain. Near the airports themselves, the controlled airspace reaches down to ground level, and the region is called a control zone (CTZ). A schematic diagram of these divisions is given in Fig. 8.1. The nomenclature and dimensions of airspace regions is subject to some national variations, and the description here is as non-specific as possible. Within airways, and in the TMA and CTZ, aircraft plan to fly along predefined routes, but may be vectored on alternative routes by the ATC controller in charge of the airspace. These are the highest category of ICAO airspace –Category A. This implies that all aircraft are subject to control, and as a consequence are assured separation from other traffic by the service provider. To be eligible for this service the aircraft must be appropriately equipped, with a range of redundant communication and navigation systems, and the crew must be licensed and trained to fly in all weather conditions and to be familiar with the range of systems on the aircraft type. In the TMA the planned tracks to/from the airspace boundaries and airports within are called standard instrument departure routes (SIDs) or standard arrival routes (STARs). They are created within airspace planning departments employing specialists at the task, whose knowledge of operations must extend to knowing how instrument procedures affect aircraft in terms of maneuverability and performance, and who must also be conversant with the most minute details of navigation accuracy and ATC separation criteria. While these do not appear complicated, the detail within them is considerable. Once they are defined and published (in the national Aeronautical Information Publication (AIP)), aircraft plan to fly them, and the ATC service responsible for the route will issue _clearances_ in such

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a way that conflicts are avoided and capacity is used effectively. Outside airways, in the Category G airspace where there is no obligation to submit to control, ATC will often provide an advisory service. The shades between these two extreme conditions (in Categories B through to F airspace) are significant in operational terms, but they are not considered in depth in this description.

The SIDs and STARs serving individual airports tend to be the responsibility of the local ATC unit, the now familiar _control tower' and the closely associated _approach' radar unit.

(It is important to note that the latter unit is rather inappropriately named as it handles both approach and departure movements and is especially involved in sequencing and handling arrival and departure traffic coordination.) The control tower staff also exercise responsibility for movements on the taxiways and the apron, so an aircraft cannot leave a stand until the control tower issues a clearance, and in turn they are unable to do this until there is an assurance from the local ATCC that there is capacity to accommodate the aircraft in the airspace it is about to join. Thus the airport is a servant to the ATCC, and while this has always been so, it was almost unnoticeable until the early days of jet operations, when en route airspace capacity first emerged as a serious service issue. The remaining sections of this chapter deal with the mechanisms of ATC, handled in a simplified way, but as objectively as possible, with interest concentrated on their consequences for viability, compliance, efficiency and effectiveness. The way that air traffic will change in terms of the forces it will have to face (and uncertainty regarding the best solution likely to emerge) is then explored in the final chapters, and the mechanisms and scope of those organizations responsible for ANSP modernization throughout the world will be revealed.

Separation minima

The concept of separation minima is at the heart of ATC operations. The principle is intrinsically simple; there should be a minimum distance between two adjacent aircraft that will never be infringed. The minima are expressed



Horizontal and vertical separation requirements as horizontal and vertical separation distances (Fig. 8.2). If the minima are infringed then the situation, even if there is no operational consequence, is regarded as serious enough to warrant investigation. This is done to determine if any lessons have been learned from the experience. For example, knowledge of the frequency of infringements can be used as evidence to refine the apportioning of risk to operating procedures. This is occasionally necessary, such as when refining separation standards as CNS system improvements are introduced. In recent years the results of incident frequency analyses have shown to regulators that further improvements in system positioning accuracy will not necessarily count for less separation without inviting an unacceptable increase in the capacity concerns. International minima are set in ICAO Annex 11, and the national authorities in each country take on the responsibility to apply these. Sometimes they impose their own variations, when they have been ratified by ICAO. Horizontal separation minima were at first expressed in terms of time (always minutes) and vertical separation in terms of distance (e.g. 1000 ft). Horizontal distance minima (expressed in nautical miles) appeared when real-time surveillance, provided by radar, was introduced. As technology has delivered new capability, some of the minima have been changed over time.

Vertical separation minima will be discussed first. When these were first defined in the 1930s, they were based on the crew 's ability to maintain a constant barometric altimeter reading. A separation of 1000 ft between opposite direction traffic in all circumstances was required, which applied up to 29 000 ft. In higher airspace regions (routinely used only after jet aircraft entered service in the late 1950s), the vertical separation criteria were increased to 2000 ft, because the barometric altimeter is less sensitive in the more rarefied air. These conditions remained unchanged until the early 1990s. In 1990, when aircraft were appropriately equipped, in terms of higher accuracy height detection capability, reduced vertical separation minima (RVSM) standards were introduced that effectively extended the 1000 ft separation criteria into the upper atmosphere. This doubled the capacity of airspace in the normal jet airliner cruise regime and was a very welcome capacity development.

collision risk, which is one source of Consider next the evolution of horizontal separation criteria. Initially in en route phases of flight, time was used. The reason was simple. The ATC staff had no way of seeing the aircraft they were controlling (unless they happened to be very close to where the controller was located, and the skies were clear). They depended on the crew navigating a predetermined route, which would pass over radio beacons, and reporting on radio when they were over the beacons. These became known as reporting points '. If a crew was setting off on a route between two points that were 75 nautical miles apart and were cruising at 150 knots, they could be expected to take 30 minutes to fly between the two points. The controller would acknowledge a radio report on passing the first point, at say 14:23 hours, and would expect the aircraft to report at the second point 30 minutes later, at 14:53 hours. If another aircraft wanted to fly the same route, a 10minute separation minimum was applied. No aircraft could fly the same route, at the same level, unless they were expected to remain at least 10 minutes behind the previous aircraft, at all points along the route. This was called procedural separation. If the first aircraft went ahead as quoted above and a second aircraft appeared, and it travelled at the same speed, it could pass the first control point at 14:33 hours, and thus would be expected to arrive at the second point at 15:03 hours. However, if it cruised at 225 knots, it could reach the second point after only 20 minutes of flying time, so if 10 minutes 'separation was applied at the first point (meaning it passed there at 14:33 hours) its estimated time of arrival at the second point would be the same as the first aircraft. Clearly this would not be acceptable. The controller had to work out that the acceptable time was 15:03, and thus the first control point could not be crossed before 14:43 hours. The time separation at the second point was the critical aspect in terms of meeting the minima (10 minutes). Procedural separation was safe, but intrinsically it was wasteful in the way it allocated airspace, in that the flow that resulted was not

orderly or expeditious. However, this did not have significant delay consequences while aircraft movements were few and far between, as faster aircraft were usually able

to use a higher cruising level. As radar was introduced, aircraft were allowed to pass one another using a horizontal minimum criteria based on distance while they were within the surveillance coverage of radar stations. In good circumstances this could be 5 nautical miles (as seen by the controller on the radar screen).

It is important to bear in mind that the aircraft might be in cloud and totally invisible to one another. The system still did not let aircraft follow one another at less than 10 minutes'separation. (If 5 nautical miles was to have been substituted the time difference at 480 knots would have become a mere 37.5 seconds, which would beg the question of wake-vortex upset, and furthermore the system safety case would be in jeopardy overall if the one sensor

that was relied upon – the surveillance radar – failed.) There was also the question as to how well synchronised the time-keeping systems were in

different aircraft. However, if two aircraft were on opposing courses and separated by at least 1000 ft vertically, if the lower aircraft wanted to climb, the controller could now initiate that process as soon as he or she was assured, by radar surveillance, that the aircraft had passed and that there was at least 5 nautical miles of separation between them. The equivalent procedural process would have required the aircraft to reach the next reporting point that the

higher traffic had already passed. Radar surveillance therefore improved en route airspace capacity enormously. In train'aircraft were spaced at 10 minute intervals, so safety considerations still limited the capacity of a level in an airway to just six aircraft per hour.

There were circumstances when the separation was reduced, such as when aircraft were flying in regions where radar surveillance was continuous, and especially if the ground system had conflict-detection software that could determine the relative shift in longitudinal spacing between traffic. However, if this was not possible beyond the handover point where aircraft fly from an intensively monitored region to a part of the world where surveillance is of poorer quality, the separation criteria pertaining to the lower-surveillance quality region had to be applied. Interestingly, this situation has existed on all traffic bound between the USA and Europe, in both directions, because over an ocean area the ability to track aircraft has been non-existent. Almost all long-haul operations throughout the world, until recent times, have been severely compromised by these circumstances.

The above limitation could be about to disappear, as the introduction of autonomousdependent surveillance (ADS) effectively causes each aircraft to report its position every few seconds. ADS-B (the B standing for broadcast ', meaning that data are receivable by alllisteners and not just a recipient list) has been introduced over the Pacific and Atlantic Oceans and will soon revolutionize operations over deserts too. It allows ground-based staff to monitor aircraft in real-time, because the data-link conveyed position reports can be digested electronically and shown on a radar-like plan display. This is an example of where the capability that has been introduced under another heading – the operational environment (Chapter 4) – has played a significant part in rewriting the way that ATC solutions are implemented throughout the world. This is a clear example of how the holistic approach to airtransport problem-solving will bring benefits for users, even if the cost of implementation is their own to bear and the credit appears in someone else's domain. The examples so far haveapplied to in route operations, but the same principles apply to operations in the vicinity of airports – the control zone and

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TMA. The way that aircraft are collected in and sequenced into a civil airport and the way that aircraft departing the same airport are threaded through the arrival traffic are the operations that set limits on the capacity of an airport.

First, arrival flows are directed towards an initial fix, and in the case of large airports there may be two or more fix points. These are the locations that are sometimes called stacking points, for if delay has to be introduced the aircraft will be instructed to fly a roughly circular pattern based on the point, which will tend to be a nevoid location (invariably a VOR/DME). While beyond this point the aircraft will have a plan that says it will fly a standard arrival route (STAR), it will not normally expect to do so exactly, as from this point the aircraft tends to be sequenced by a controller using radar-generated information. (The value of the STAR is once again rooted in the safety culture. If the aircraft has a communication system failure, it will proceed according to the STAR procedures, and the ATC system will maintain separation byvectoring other traffic out of its way.) The approach service controllers at all but the very simplest of airports are radar-equipped facilities, and are allowed to vector in-train 'aircraft and may even need to merge lines from more than one fix point in order to create a steady stream of arrivals to the runway.



Figure 8.3 shows a set of STARs that are typical of those used to support the use of a busy airport runway.

The use of radar surveillance assures a similar level of approach flow rate, irrespective of the weather conditions. In fact, in very severe weather (Categories 2 and 3 low-visibility conditions are described in more detail later), the capacity must diminish for the simple safety reason that post landing the crew and visual ATC control procedures must adopt wider time-separation criteria. During the approach phase the vertical profile of the aircraft is monitored, to bring it through the fix at an altitude that is always usable . Then the aircraft is descended, typically to between 1500 and 3000 ft or so above the airport elevation, as it joins the final approach path, which it will fly at a constant speed from about 10 nautical miles. If the sequencing can attain a steady distance of 4 nautical miles between succeeding movements, and the approach speed is 150 knots (2.5 nautical miles per minute), the aircraft will arrive at 1.6 minute (= 4/2.5) apart. This is equivalent to 37.5 (= 60/1.6) arrival movements per hour, and i

Example airport STAR (London Heathrow, runway 27R) (Source: Racal AERAD (1999), now Thales). This is not a complete or up-to-date chart. Do not refer to for navigation. attainable only

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if there are no heavy'(significant wake-vortex-generating) aircraft in the arrival flow. At commercial airports it does not get much better than that, and the controller team that facilitates this kind of operation is one that delivers tremendous value at the expense of great concentration. It is a task that is skillful and labor-intensive, but at the same time it is rewarding to those who do the job.

Meanwhile departures must be accommodated. They can usually stream off a dedicated runway or be slotted between arrivals. In the latter case the attainable arrival capacity will usually fall, because the departure must be airborne in time for the arriving aircraft to be cleared to land at a safe distance from touchdown. The considerations of this kind of operation have been spelled out in Chapter 7 on airports, where it was shown that capacity would be perhaps 40-45 movements per hour, at best, with 50% each dedicated to arrivals and departures. A departure-only runway can cope with up to 60 departures per hour. To achieve this, it needs access to sufficiently free airspace, the traffic sample must be ordered in such a way that following aircraft do not catch up on preceding aircraft and wake vortex issues must be handled without any capacity-impact implications. Thus, a single runway airport can handle up to 40-45 movements in its peak hour, and an airport with independent arrival and departure runways can handle up to 37.5 arrivals and as many as 60 departures per hour. If an airport has more than two runways, the interactions between them, and associated with the airfield configuration overall, can achieve more capacity. It is ATC procedures that set these constraints. These are so closely allied to separation procedures, which have shown no inclination to exhibit improvement when automated systems have been used to replace controllers, that the airport-based aspect of ATC seems certain to be capacity- capped at levels like those quoted forever. Although the research to date has suggested that the door is shut, there is still a desire to prise it open, and optimism continues to encourage investigation in some development teams.

Airspace sectors

ATC is about vectoring aircraft, and because there is so much decision making involved it is a human based business, so the capacity of the human being to handle more and more aircraft simultaneously is a necessary limit on the capacity of ATC functions. Workload models are used to assess the capability of controllers put into certain control situations, and these are usually based on empirical evidence of capability that has been derived from assessment projects. If within a sector the simultaneous arrival capacity is assessed to be 15 aircraft and the typical path through the sector is 45 nautical miles long, the time that it will take for an aircraft to pass through the sector might be 10 minutes. This would indicate that 1.5 aircraft per minute can enter the sector – or 90 per hour. The longer the typical sector path, and the longer therefore the transit time, the fewer aircraft can enter in eachperiod of time. Such an assessment depends on knowledge of the traffic configuration, with merging and crossing points causing the biggest reduction in capacity, which might mean not more than, say, eight aircraft on the sector simultaneously. In the situation considered already (10-minute average transit time) this would approximate to an aircraft joining the airspace every 1.25 minutes – or 48 per hour. If this is too low the sector size must be reduced, meaning that an additional sector is introduced; thus, more controllers are needed to handle the flow along a given route as it becomes more complex and longer. If there is no infusion of technology that will assist in handling higher levels of workload, the ATC staff levels needed to support a given region

(an en route area or an airport) will inevitably rise as traffic levels rise. The rate of increase can be assessed empirically, but the inclusion of more and more handovers 'between controllers means that a controller has to devote more time to communications within the ATC system, and the cost-effectiveness of services can often fall as traffic level targets rise. In Chapter 13, where modern data-handling techniques are described, their potential to break the mound will become more apparent.

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The sectorization of airspace is a complex planning task. Once a configuration has been determined, its planners will test its effectiveness by using computer- based simulations that require large facilities (and draw on controller resources). This is almost reason enough to resist the resectorization of an ATCC, or TMA, region, but additionally there is a vast



Airspace sectors (Source: UK NATS).

amount of re-training involved, and the new airspace procedures affect aircraft worldwide. Consequently, the process is applied sparingly, and when it does happen it will have been meticulously pre -planned and the new flight instructions promulgated widely with substantial warning. As an example of the complexity of this sometimes-invisible configuring of airspace, a lower airspace sector map of London ATCC in recent times is shown in Fig. 8.4. The inevitability that higher traffic loads mean more controllers are needed has been behind the gradual expansion that has been borne stoically by government-owned ANSP organizations over numerous decades. However, privatized businesses have greater difficulty in justifying their increased outlay per movement to customers who are shaving cost models to the bone. This is one example of where the privatization model does not work as well within the ANSP sector as it does in the airline and airport sector. This has not been a deterrent to the off-loading of what is a capital-intensive business in many countries, however, and as the situation is not rigorously regulated, there is a fear factor associated with the expansion of privatization policies into areas where ATC investment needs are substantial. This becomes more critical if there is a poor supply of qualified staff and a lack of ability to train people to use the latest systems.

Capacity, demand and delay

The most well-documented tool in the arsenal of ANSPs, when they come to justify choices that balance the desire for orderly and expeditious service within their area of responsibility, is illustrated in a traffic flow diagram, where delay, capacity and demand are all related. This is shown in Fig. 8.5. It is a graph that has numerous applications, such as describing the relationship between service, demand and queues affecting passenger flows through an airport terminal, or the way that surface-based transport systems – railways and highways – operate. Its applicability to airspace issues is no different, albeit this is a three-dimensional capacity issue with vehicles that cannot stop and can suffer perilously if they run out of fuel. Essentially, the graph shows that the more orderly the flow (in which case the smaller will be the value of s), the closer a system can run to its capacity limit while causing a given level of delay (averaged over all movements). If the demand was perfectly regular (implying that all aircraft were spaced evenly from one another), s = 0, and the delay curve would rise from the origin, proceed straight up the Y axis (i.e. no delay at any demand level) and, as demand reached the capacity level, the line would go horizontally to the right. This is a theoretical solution, not least because aircraft (indeed any set of vehicles or individuals in a system) operate at different speeds



Capacity, demand and delay relationship.

Additionally, aircraft can be at different levels and can be affected differently by the weather, over time or over a region, and so on. Therefore, s cannot equal zero, and there will always be a delay associated with a level of demand. That delay will increase as demand approaches the capacity of the system. In ATC, in aiming to meet the request for an orderly 'flow, the system procedures assist in minimizing the value of s. The controller does this without the use of mathematical processes. It is

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through procedures that make appropriate use of the capabilities they have available and the application of specific rules that ATC has, consistently and over many decades, achieved good capacity/delay results. The information at hand to a controller, and upon whose values decisions are made, is associated with various systems, which have changed over time. Examples have already been given in this chapter, with radar surveillance the most significant example of all. Continuing to resolve ATC problems while achieving acceptable levels of service provision is the major systems 'issue that civil aviation faces in the future, and the technological capability that will be called upon is likely to be profoundly different in the future to that used in the past. The newer systems will call upon CNS capabilities that have already emerged in the study of aircraft, airlines and airports, so this chapter is not a stand-alone story. However, it concerns the one area where civil aviation 's future is most likely to flourish or fail. Note that Fig. 8.5 does intimate that there is an average delay level per movement above which system performance is regarded as unacceptable. The higher the acceptable average delay level is set for a given service variation factor; the more capacity can be attributed to airspace. This is a clear indication of trading capacity and service performance. The definition of _acceptable average delay 'is a vital research initiative, and increasingly it is among the most vital of all air transport capacity limitation variables. Where the line is set is more than an academic question, and the confidence in where it is and how the service variation factor _ is influenced will relate to topics discussed in later chapters, as the roots of the answers that are needed are not the property of the ANSP alone but are often found deep within the user components of the system.

A brief chronology of air traffic control system Evolution

The description so far has shown how the ATC system applies the procedures that have evolved over the last 50 years or so. The fact that the mechanisms of the ATC system have changed is also relevant to the rest of the story, because change must be accommodated in such a way that a system can evolve. In the ATC profession there is less latitude for radical evolution than in any other components. While airliners are being manufactured from newer materials, airlines are adopting new economic paradigms and airports are extending runways or razing old terminals to the ground, the ATC system has to change in a more incremental manner. This section expresses the way that many of the changes already enumerated have been implemented, and a point to savor from the four stages that are identified and described is that while the ATC systems in the busiest parts of the world have undergone all of these transitions, there are places where the first, and most elementary, stage is still the normal operating mode. Whatever the transition proposed to carry ATC development forward from Stage 4, it must be compatible with the transitions from Stages 1, 2 and 3. This is a very significant system design task, which will require the cooperation and understanding of all air transport system stakeholders

Stage 1: procedural ATC system

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Stage 1 ATC systems use procedural methods. They require: that aircraft file a flight plan ', a declaration of all relevant flight intentions. a telecommunication system to distribute the flight plan to all relevant ATC units. paper strips, at the ATC units, on to which flight details are written. reporting points 'over which aircraft report their positions as they fly their routes. a radio system (invariable radio r/t) to communicate between aircrew and ATC units. The region over which an ATC authority assumed control became known as the flight information region (FIR) and the routes along which separation was assured became known as airways '. The system depended on the adoption of an internationally recognized flight plan and the provision of a ground-based communication system, called the (AFTN). This has changed considerably over time but has remained capable of supporting the same general requirements overall. The basic infrastructure of a Stage 1 ATC system is shown in Fig. 8.6. There are two issues to appreciate in the human interface **display 'andcontrol'. Displayis**

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the function of presenting information in a way that is understandable to the person tasked to make decisions. Control is the function whereby decisions having been made, the instructions can be issued. It is desirable that the display function also allows the user to keep a record of the instructions issued, so that the controller – or anyone working



Schematic diagram of a Stage 1 (procedural) ATC system

alongside – has a complete record of the situation. The information they get is called situational awareness '. In this most elementary of systems, the most significant display element is a large rack on which paper strips, about 15 cm long and 3 cm deep, are held in special strip-holders. The flight plan progress strip (FPPS) has colours, which convey information (eastbound, westbound, crossing traffic, etc.), and data written on them, presenting such information as the aircraft 's call sign, requested level, route and destination.

A controller has a strip for each reporting point in their sector. This means that there will be a number of strips per aircraft, and the board of strips can only convey situational awareness 'to an individual who is trained to interpret their data. Paper strips are beginning to disappear, but in many ATC systems worldwide this is still the preferred method of presenting and recording information. The paper strips are bundled and archived each day, and saved for several weeks, in case an incident requires investigation. In terms of the route that an aircraft flies, the ATC controller is responsible for the clearance 'and the aircraft crew are responsible for guiding the aircraft to where they are instructed. They follow the route and obey clearance instructions, which the ATC controller updates as the aircraft passes decision points. Aircraft are able to make requests and an ATC controller can re- clear an aircraft to a new route or to a different level, if the strips present evidence that there is space to accommodate the aircraft. The mental picture of what the ATC controller and the aircrew in the airliner look at, day or night, good or bad weather, in their respective places of work needs to be kept in mind. As ATC system development has occurred, it is these components and the way that they allow information to be used that will be seen to have changed.

Stage 2: procedural ATC with radar assistance

In the 1960s ATC began to use radar in earnest. Some radar applications had arrived after World War II, with surveillance approach radar (SAR) serving the aerodrome ATC units, which developed the approach 'function using this system. The SAR radar was a short-range, relatively narrow field of- view and fast-rotating, radar. The approach path could be seen on the screen, and the aircraft was a small target that could be guided. Some radar installations also had a vertical scanning unit, so that the plan and side view of the aircraft 's progress down the approach was visible to the approach controller. This allowed talk-down 'approaches to be conducted in low cloud base on runways that had good approach lights. In the 1960s ATC began to use radar in earnest. Some radar applications had arrived after World War II, with surveillance approach radar (SAR) serving the aerodrome ATC units, which developed the approach 'function using this system. The SAR radar was a short-range, relatively narrow field of- view and fast-rotating, radar. The approach path could be seen on the screen, and the aircraft was a small target that could be guided. Some radar installations also had a vertical scanning unit, so that the plan and side view of the aircraft 's progress down the approach was visible to the approach controller. This allowed talk-down 'approaches to be conducted in low cloud base on runways that had good approach lights,

even if they had no navigation aids. At airports that had ILS (Chapter 4) the radar could be used to monitor aircraft but was used more routinely to guide aircraft into the narrow beam of the ILS, so that the crew could establish a stable approach as soon as possible. Note that if SAR was used and there was only one radar screen, the operator took about 10 minutes to talk down' and then pick up the next aircraft to sequence, so the runway capacity was approximately 6 arrivals per hour. This was a big improvement on being shut because of low cloud, but the system did not provide as much capacity as busy airports wanted. Where an ILS was available to provide direct guidance to the aircrew, the approach radar operator now simply sequenced 'aircraft to a point where they could acquire the ILS guidance signal.

Movements could be monitored during their approach, and as aircraft could be brought in as close as was safely sustainable, the ILS solved the runway approach capacity problem many decades ago. This kind of operation has remained almost unchanged, apart from improvements attributable to daylight-viewing 'radar displays and more sophisticated electronic data-exchange systems, especially between the airport and the local ATCC. Within the ATCC the arrival of radar, while welcomed because of the surveillance improvement it offered, was more difficult to accommodate, because for many years the transfer of radar data by landline was regarded as too unreliable. Long-range area 'radarswere located in strategic positions (often for military purposes and used on request by civilian ATC) and a controller located at the radar site could communicate directly with the ATCC procedural controller. These became known as the radar controller and procedural controller, but as computers and landline transmission of data improved this proved to be a transitory architecture. There may be a few ATC units where this practice still exists, but no such unit would ever be built nowadays. The very least facility that will be considered is a system like that described in the next section.

Stage 3: the first-generation 'automated' ATC system

In the ATCC, radar and computers were combined, creating an installation that was a major leap forward in the way that radar provided real-time surveillance within the ATCC (see Fig. 8.7). Now ATC was no longer dependent on the periodic reports that were given over reporting points. Indeed, aircrew often no longer had to pass on such information. In addition to getting primary radar, which

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detects aero planes (and a lot more) and presents a blip ', there was a surge of interest in the secondary radar. This could detect aircraft with an ATC transponder on board and determine a code that identified the aircraft and the aircraft level (primary and secondary radar are described in Chapter 4). These radars were placed strategically around the region and the information was encrypted on to a landline and sent to the ATCC. At the same time, the signal that had made teleprinters tap out flight plan data for many years was ideally suited to being read and interpreted by a computer. Two large computers were usually installed, and their functions were: The flight -data processor (FDP) collected the flight-plan data and kept an up-to-date log of aircraft call signs, the transponder code they were allocated and the route they would fly. The route information was used to print paper strips (no longer hand- written and often only one per flight per sector now) and the transponder code and aircraft call sign information was sent to the second computer (next).



Schematic diagram of a first-generation _automated' ATC system.

The radar-data processor (RDP) collected the primary and secondary radar data and mosaiced'(combined) the information from various radars, so that the controller was not limited to seeing a circle about one radar. So long as the radar could reach there, they could see into any part of the sector they controlled. The secondary radar collected each movement 's transponder code and the FDP data were used to correlate this with the radio callsign. The computer generated a label 'that was attached to the radar blip on the screen.

Each relevant blip was thus tagged with a label that moved with it. If the secondary radar and transponder could determine the aircraft level, this information was also added to the label. It could include an arrow that showed if the aircraft was climbing or descending. It was common practice also

to add a letter code, indicating where the aircraft was heading – to an airport in the region or an exit point into another region. Two controllers, situated side-by-side, now cooperated. One handled telephone message that told of aircraft coming into the sector, or originating messages elsewhere that told them to expect traffic; this controller was called the strategic controller. Roles included determining strategy, and this left the tactical controller to determine tactics, thus directing aircraft by issuing instructions or responding to requests on the radio. The division of roles was not usually so clear-cut. Most pilots were still flying in aircraft that did not have electronically integrated display systems, but aircraft were getting faster, the navigator has been removed from the flight deck and so pilots had to work hard to conduct navigation and simultaneously keep ATC informed of position. They had workload problems. However, even they benefited greatly from the secondary radar and transponder, as it kept the ATCC staff informed of their exact position – in three dimensions – and it could even measure their speed from successive radar contacts. The need for crews to pass information diminished and the utilisation of radio frequencies was considerably enhanced, especially in the TMA, where the majority of aircraft were climbing and descending, and controllers benefited from having a greater proportion of time available to judge tactical moves and discuss strategic decisions with their partner. Controller workload was eased considerably by these developments and contributed directly towards capacity improvements that were very significant, but almost unheralded, in the 1960s and 1970s.

The controllers 'workstations have changed dramatically. They had a radar display (it was sometimes upright and sometimes flat), and thus they had a real-time picture. This was what allowed horizontal separation criteria to be reviewed and the capacity improvements already described to be achieved. While the synthesis of radar and computers did a great deal to improve the service attributes of ATC systems, the rate at which technology was infused into airliner flight decks, as described previously in Chapter 5, came along a little later. Aircraft with electronic flight deck displays and flight management systems simplified the interpretation of sensor information and provided displays that improved crew situational awareness 'very significantly. These systems were in almost 50% of the world jet airliner fleet by 1990. The ATC controller was often unaware of how confident the crews were of their positions and having to apply separations that they felt they were able to monitor better was often imposing delays that brought rashes of crew complaints. Aircrews did care that failure cases were being considered, but they knew that the skies were still relatively clear and the clearances they were getting were not making the best use of the airspace capacity that was available. It was much more difficult to create an information handling and display system of equivalent quality for the ATC system, but around the late 1980s that kind of capability began to arrive in ATCCs.

Stage 4: current generation radar and computer-based ATC systems

Before looking at how the systems have evolved in recent times, the dilemma of en route airspace capacity and its only solution to date flow control needs some consideration. The effects of en route congestion were first seen in North America around the West Coast and East Coast conurbation regions in the 1960s. It was apparently a geographical issue, and there was some optimism that it was an issue of the time too, as jets and turboprops, and even a few piston engine aircraft, with disparate speed capabilities plied the routes in those days, and this range of types certainly contributed to capacity dilemmas. Blanket speed restrictions eased a lot of capacity pressure, and even though this was successful, airspace planners recognized that capacity was a commodity that they would have to ration 'to users. They began to plan for coping with more en route movements by collecting schedules as they were planned (perhaps six months ahead of the operation being performed) and to use computer simulations to forecast demand on busy routes. Eventually they began to model the whole of the continental US airspace. In Europe the situation was growing as serious in the same

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period, and an equivalent flow assessment exercise became commonplace in its ATC research centers.

Behind the scenes, in that it was not a part of ATC as it was known, the flow- control function grew. It was manned by ATC staff, and their job was to assess demand and to redistribute it if possible or impose delays. This was safety over-ruling expeditiousness, and it was the most controversial ATC topic because it was apparent to all users that the airspace just was not full'. Flow control was eventually accepted as a component of the ATC system, and its presence in a system nowadays reflects that premeditation is exercised instead of handling aircraft first come, first served '. This development coincided with the introduction of the term airspace management. A modern automated ATC system is illustrated, in a very

schematic manner, in Fig. 8.8. The working practice established in the previous generation of systems has been retained, with tactical and _strategic controllers, but now they work cooperatively, rather like the captain and first officer on a modern flight deck. The information sources are not very different to those shown previously, but some telephone routines have been replaced with digital message systems, for example, to hand over an aircraft between sectors or even ATCCs. The flight-plan data are taken via electronic links as the majority of plans are lodged many months before departure.

The FDP and RDP functions of the previous generation have had a flow- management processor (FMP) capability integrated, which works with the pan-national flow-management system (for the USA or Europe), and a support-information system (SIS) processing function was also integrated. The latter function handles weather forecasts and reports, as these also come via digital links.



A modern automated ATC system.

There is little intrinsic difference in the attributes of the ATC service that can be offered, although the need to maintain a very strict procedural floor 'has been abandoned, especially in constrained areas such as the TMAs. The paper strip has been replaced by electronic displays that can be as small as the previous generations 'label', or expanded. This might be achieved simply by passing a cursor over a label, revealing a range of information that would have been on the strip in paper days. The radar-data processing complexity has been increased with integration of the conflict-detection probe. This is a device that evolved slowly through about 25 years (between 1975 and 2000). The conflict-detector is a flight-path predictor tool and will work out where aircraft should be in the future - typically up to 15-20 minutes ahead. This is not easy to do in a busy TMA. If a potential conflict is detected, the system will alert the sector controller, who is obliged to address the conflict with an acknowledgement and probably a re-clearance to one or more aircraft. In its early incarnation this tool was disliked. It was seen to be big brother 'watching over the controller. That negativity was dispelled with some careful development that is a milestone in human-system interface design. More importantly it has been accepted because it does keep an eye on the controller, who can be stressed by time-related circumstances. ATC controllers are not automated individuals. They have good days and bad days. They have traffic flows that are good some days and bad other days. Either scenario is a frustration but put the two together and throw in some lousy weather to boot, and the potential for a catastrophic event escalates. The conflict-probe will not so much add to the controller 's worries as alert them, and others (including their supervisors), that this is a situation that needs to be brought back towards a more manageable set of parameters.

There was a concern that, one day, ATC would rely on such a device to such an extent that it would be unsafe if the device failed. It was a fair supposition in the 1970s and 1980s, but around 1990 a new airborne device came along – traffic conflict and alerting systems (TCAS), which have been described in Chapter 4. This is autonomous and is designed to alert a crew to an aircraft coming dangerously close and to suggest a suitable avoiding action. Its parameters are more constraining than the conflict-detection probes used in the ATCC, and as such it is a belt and braces (or classic example of a dissimilar redundancy solution) to a very critical safety case. TCAS has been mandatory on almost all air-transport aircraft since about 1990.

The way that ATC systems have evolved, creating capacity that has been so readily soaked up, and yet maintained a consistently high quality of service, against safety, orderly and expeditious requirements, has been a largely unheralded success story. As the next stage of the book takes a view across the whole panoply of aircraft, airline, airport and airspace issues, the way they interact and how they can be used to combat or restructure limitations. It is suggested that the doomsayers can expect to find no comfort. There is every indication that the technology that will be needed to assist in this task is already on the shelf or close at hand. It is a matter of developing the skills to know how to present capability to relevant stakeholders across all elements of the air transport system. They need to be shown the big picture ', which will be the air transport industry's situational awareness' test. Aerodrome air traffic control equipment and Operation

It has been commented that airfield ATC units have not undergone the same scale of development as ATCCs, but the equipment they use and the results they post have been achieved through a lot of procedure development. The way that airfields operate when low-visibility procedures (LVPs) are in force deserves a special mention. Pre-radar, aircraft had to find their own way down the approach to a cloud break that would typically be at several hundreds of feet, even over a flat aerodrome. The capability to vector using radar, which came along post-World War II, and then to vector on to an ILS and to monitor the approach, in the early 1950s, has been explained. The ILS was the approach aid that suited all needs, although radio electromagnetic spectrum congestion did threaten to see the ILS

usurped by a device called the microwave landing system (MLS). This development has not transpired, however. The ILS was, and still is, used as the main guidance source on landing for aircraft. It is often linked through the automatic flight control system (AFCS) and can even incorporate automatic landing capability. ILS allows the crew to descend, with confidence, in much lower-visibility conditions than they can fly through when handling the aircraft manually. It assures the crew that they will emerge from the cloud base exactly in-line with the runway centerline, or even be delivered right into the runway if the visibility is truly atrocious. Three distinct sets of approach operating minima are defined for aircraft approach operations in low-visibility conditions. These are:

Category 1. These are operations conducted when the cloud base is not less than 200 ft AAL and the RVR exceeds 600 m. These are decision height and visibility minima applicable to a competent aircrew conducting a visual or radar-assisted approach.

Category 2. These are operations conducted when the cloud base is not less than 100 ft AAL and the RVR exceeds 300 m. These are decision height and visibility minima applicable to a competent aircrew conducting a visual or radar-assisted approach, with flight-director assistance, or a Category 2 cleared automatic flight control system. A go-around (missed approach) can be instigated at down to 100 ft in height.

Category 3. These are operations conducted when the cloud base is below 100 ft AAL and the RVR is less than 300 m. There is no decision height and the crew have to be assisted by an automatic landing system. There are three weather minima subsets in this category:

Category 3a: 100 ft maximum cloud base/300 m maximum RVR

Category 3b: zero ft decision height/75 m maximum RVR

Category 3c: zero ft decision height and zero m RVR - total fog.

(Note that the runway visual range (RVR) is a definition of visibility on a lit runway in fog and can be regarded as 1.5 times the reported meteorological visibility. Decision height and cloud base are also linked in a similar way.) Automatic landing had shown that such landings were possible as long ago as the mid-1960s, but it was only in the 1980s that the systems were widely used. They required aerodrome ATC operations to be equipped with their own very sensitive aerodrome surface movement radar (ASMR) or, in the classic safety case, they could only allow one aircraft to move on the airport at any time. It was soon possible with ASMR installed at all major airports in Europe and in North America to operate almost routine timetables in even dismal fogs. The aerodrome lighting of the approach, runway and taxiway must be of a high standard, and the workload for controllers when they are managing a number of aircraft simultaneously is considerable. Overall, at airports, the ATC function has evolved to ensure that capability limitations determining runway and airport capacity are only a constraining influence in the most severe weather conditions. It has therefore been in the en route control regime where attention to capacity limitations has been concentrated.

ICAO future air-navigation systems

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The capabilities of some of the emerging, and yet relatively unused, technologies have not been neglected. At this unique point in time some very fundamental work has been taking place in committee rooms and been implemented in laboratories over the last 20 years or so. Many of the systems owe their presence to outcomes from the work of the ICAO future air-navigation systems (FANS) committee.

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he FANS committee was not set up to solve ATM 's problems. ICAO was aware that ATC systems would need to evolve and sought to define a functional framework - not a definitive system - within which new operational concepts could be enabled. The committee comprised representatives of aircraft and systems manufacturers, regulatory authorities and airspace users, as well as ATC staff. They were people who had the best knowledge of CNS developments. When the committee was formed, in the late 1980s, the state-of-the-art in these fields and the emerging capabilities were thus: . Communication was routinely provided by voice radio (either VHF or HF), but there was increasing use of digital data-link (such as Mode S) and satellite voice communications over oceans and sparsely populated regions. It was an objective of the FANS committee formally to identify how these developments would be integrated in future operations. Navigation could use one of many techniques, but it was generally reliant on ground-based radio naiads (such as VOR/DME and ILS) overland and around airports or inertial navigation systems (INS) when over oceans. The advent of satellite-based navigation systems, and especially global positioning systems (GPS), in all regions of airspace was forecast, and its imminent emergence from laboratory to flight decks was a large part of the focus for the FANS committee. Surveillance was still usually achieved by radar, either primary or secondary (ATC -transponder based/SSR Mode A/C), but there was increasing awareness and preliminary trials of autonomous dependent surveillance (ADS). Applications expanding to cover almost all oceanic regions were forecast and given there was no surveillance at all in those regions at that time (but areas of congestion created by almost procedural 'based ATC implementation), the need for change was apparent to the FANS committee. A misnomer of the committee is that its name suggested a preoccupation with navigation, whereas it had a remit to view the complete CNS system development process. How it addressed the many technical and operational issues that were explored in a decade or so of prolonged and often very deep debate can only be summarized by taking a very general view of the conclusions it drew. Satellite navigation, of which GPS was just one implementation (many others have emerged since), was viewed as a position-fixing system, but the FANS committee resisted the temptation to herald it as something groundbreaking. GPS did offer the opportunity to know position so accurately (within 5 meters anywhere on the Earth 's surface is achievable) that the committee had to challenge every aspect of limitations, including failure cases.

In traditional safety-led style they concentrated on investigating the integrity 'of the system. They asked questions such as can GPS fail? and If it does fail, what are the consequences? 'Referring to legislation that has been discussed earlier they reasoned that the failure had to be minor '. This is a vital interpretation of safety legislation, for if every aircraft had to depend on the GPS satellites for position data, if the system so much as faltered, every aircraft could be left unaware of its position. The US Department of Defense (DoD), who had sole responsibility for the provision of GPS as a navigation service, had to submit to ICAO very detailed evidence of the failures that could occur. The probabilities of occurrence were assessed and legislation for the certification of it was drafted. (The legislation also covered any consequent system that offered a signal-in-space (SIS) that was generated from multiple sources, in orbit or otherwise, and that depended on a provider 's monitoring system to assure its integrity.) This is now international law and all subsequent systems, such as Gleans, EGNOS and Galileo, have had to undergo the same scrutiny. The international law expresses what can be called minimum navigation performance specifications (MNPS). These are not new as they were used to authorize the application of INS in situations that had led to procedural 'separation improvements in the 1970s. That is the technical benchmark. Attention was also paid to the cost of these systems as they require huge investments. They dwarf most other technical projects, being long time-scale development programmer that will absorb billions (in whatever currency is assumed) and once they are in use the provider will incur operating costs that are equally massive. To run a satellitebased navigation system, which has typically 24 satellites in orbit at any time, requires the operating

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authority to launch new satellites continuously. They are relatively large and must be inserted in high orbits, so they need considerable power to do this.) The satellites must be monitored, with a full diagnostic check completed on every satellite in every 12-hour period. The safety cases depend on the latter, because any fault must be recognized and eliminated or neutralized in a specified time frame. It is all very 21st century capability, but is built on existing technology – indeed, often quite old technology (in electronic systems terms) – so that there is adequate confidence in the quality of service these satellites will offer.

The availability of position information of superb accuracy, anywhere worldwide, and the ability to capture or transmit real-time information in an almost continuous stream will affect the way that aircraft are navigated and how they communicate and operate. The flight management system (FMS), described in Chapter 4, will have better quality information than hitherto, and will be able to present information, either on its own screen or directly on to the primary flight instruments, that will ensure awareness in more complex situations than could be envisaged and used. In addition to generating steering commands for the AFCS, it will generate warnings if the aircraft is not proceeding according to plan, for example if fuel is being consumed faster than expected. The aircrew, who use the FMS to examine the implications of ATC clearances, will find they are provided with precise advice on the clearance or re-clearance they should request. In some cases the information might be passed to the ATCC automatically, using the latest digital data-link, and the response, received by the same route, will flash on the aircraft's primary flight displays and will be poised for entry into the FMS algorithms, when the crew say they want to use that input. TCAS will determine if another aircraft is close by and poses a potential collision threat, and thus provide an independent monitor to the ATC system. Meanwhile EGPWS, because it can detect and predict ground terrain, will enhance visualization of potentially hazardous situations. In recent times the PFD has a terrain-awareness warning system (TAWS) incorporated, that provides a two-dimensional plan and side elevation view of the flight path (presented equivalently as it is on the paper maps and approach charts that crews have used throughout civil aviation history), thus aiding a crew's perception of the situation. The mass of paper maps that has traditionally filled crew flight bags seems destined to be reduced to the content of an electronic memory chip. Aircraft and ATC system evolution is entering new territory.

The ICAO FANS committee has been a systems integration point, where legislative content has been defined from rigorous and systemic debate. It has been the important shelf on which air transport system operations will sit for the foreseeable future and, if the committee has done the job well, until beyond the lifetime of newly recruited current staff.

Air-navigation service providers as businesses

Moving forward into the current era, the air-navigation service provider (ANSP) role has been revealed to be one of the government-run agencies that are expanding, in terms of workload, and thus branded as an element that is suited to being privatized '. Several nations have done this, some whole-heartedly and others more circumspectly, retaining majority equity in the government or, if relinquishing financial control, retaining boardroom control. This is circumspect when a nation appreciates that the implications of a failure to perform have a potentially major impact (some would quote risk-assessment nomenclature chapter and verse 'and upgrade that to catastrophic impact) on national economic performance. There is no denying the fact that airspace management is vital to the capacity of airports overall, and while it has an apparently vast working arena, it is capacity strapped. Therefore, while making money from current operations – enough at least to cover operating expenses – ATC authorities are rarely able to handle the research and capital costs of upgrading their systems, year on year. There are other coefficients in the equation. One that must be mentioned, but will not be

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investigated in depth, is the way that civil and military operations are jointly handled and the way that prioritization of use of airspace is managed in times of conflict. The major coefficient, and one of which it can be said unkindly, in Europe that has been swept under the carpet for over 40 years is pannational ATC service coordination. The will to do something about this situation has been there since the creation of Euro control in the 1960s. The forces that shaped this organization at its foundation were very different to those that shape its actions today. Some would say they leave it with a doubtful legacy; others will point to the fact that much has been learned, good and bad, along the way. There will be time enough to reflect on these points in due course, but more than any other organization in the world, Euro control is now at the hub of air transport system 'optimization. Its ability to achieve wide ranging aims will have an impact on all those who use European airspace, which can mean aircraft operators and thus their customers from worldwide. Euro control's plight is not unique, however. In continental USA, where the scale of operations and the density of movements in the most well-used regions is still considerably greater than anywhere else in the world, there has been much less of the hubris that has been attached to equivalent development in Europe. The reason for this is absolute simple. Continental USA is a swath of airspace that is similar in scale to Europe, and it is managed by one authority, the US Federal Aviation Administration (FAA). There has been no move to privatize 'US air traffic affairs: they remain resolutely on the government agenda. It is in Europe, where 40-odd authorities apply their stamp of approval over sovereign'airspace, where _privatization' has been rife and where fragmentation has delayed progress. Within Europe, initiatives that currently culminate in the Single European Skies (SES) program me represent a salient point in time for Euro control to display the ability to be an intellectual stakeholder in the regimes that evolve in due course. At the present time, only the USA and Euro controlare able to postulate and implement the kind of radical shifts in the ATC paradigm that seem certain to be necessary to solve impending capacity crises. Meanwhile, China and much of South-East Asia gear up to handle equivalent levels of traffic in similar-sized regions. This means that they will either copy the USA, look towards Europe (which being pan-national should be able to offer advice) or do their own thing.

American researchers have canvassed in Europe and worldwide to seek compatriots and have sown the ideas for collaborative development, but the uptake has been unimpressive, largely because of the fear that _what is good for the goose is not necessarily good for the gander '. There is a fear within many of the establishments that have vested powers of authority over ATC affairs that if the world subscribes to the US paradigm, it will become subservient to their businesses too. Remedying this fear will mean that many deeply entrenched organizations must take a holistic view of the whole system, and fast. Their new perspectives have to be across the whole of the air transport system. This is difficult to achieve in any long-established organization, but if the management of vital elements has disappeared into foreign or pan-national ownership, and the political will to commodities economic needs and technical skills is no longer at the center of the strategic decision-making process, it becomes burdensome. This chapter has dealt with the mechanisms of ATC, with interest concentrated on their consequences for viability, compliance, efficiency and effectiveness. It has been acknowledged throughout that the way that air traffic will change, in terms of the forces it faces, and even not knowing what is the best solution that will emerge, is about to be explored. A point to stress is that these views are well understood in organizations already mentioned (FAA, Euro control, and

associated research and academic establishments, to name only the core) and have been well represented in papers from aircraft manufacturers (Boeing predominantly and Airbus with conviction, but less vigor). Airlines and airports have tended to be hostages to fortune, being more concerned with day-to-day performance and acknowledging that the physical capacity of their direct contributions to the system are a part of the whole and largely examining proposals for acceptability rather than contributing to the establishment of workable solutions. In that interference ', in terms of impact on the services they provide, has been clearly significant over time, their perspectives have been attributed a great deal of attention throughout this book. Their willingness to contribute has never been questioned, but their ability to explain their own paradigms with as full an understanding as is necessary for other stakeholders is questionable. There is more to airlines than the glib categories so often quoted, and likewise airports are more than just regional 'orinternational '. They have strategies that will encourage all the stakeholders to take note of impact on their own domains.

The one stakeholder with the most difficult balancing act now (and perhaps indefinitely) is the ANSP. It has been with ill-founded timing that financial viability has been accelerated up the chain of priorities on the ANSP agenda, through the application of policies that fall neatly, in the political sense, under the heading of privatization.