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COMPUTER SCIENCE
CASE STUDY: COMPUTER SYSTEMS IN AIRPORTS

For use in May 2010, November 2010, May 2011 and November 2011.

INSTRUCTIONS TO CANDIDATES

- Case study booklet required for higher level paper 2 and standard level paper 2 computer science examinations.

16 pages

Contents

Computer systems in airports

Introduction

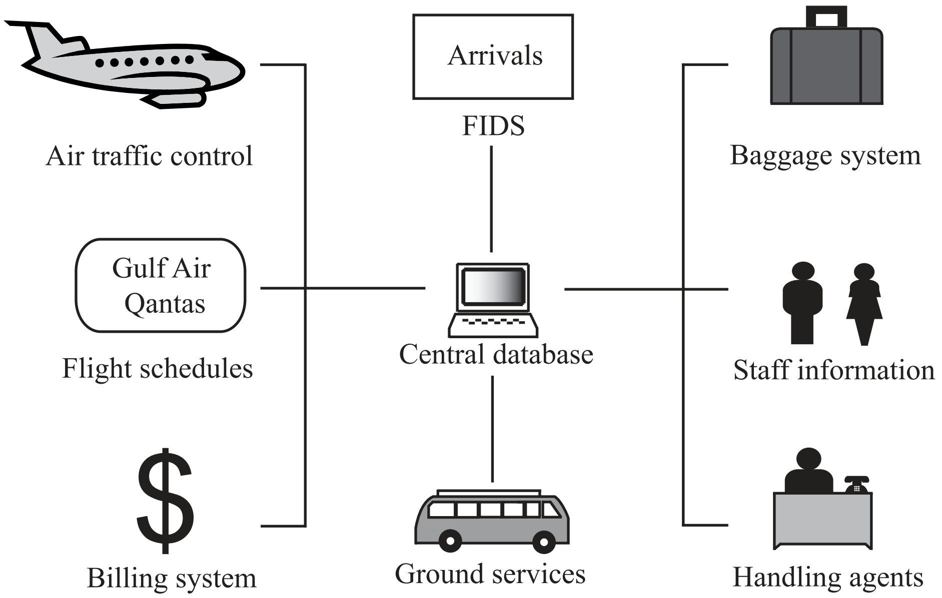
Modern airports are now highly reliant on computerized systems that provide the facilities for safe and efficient access to air travel, as well as making the airport a pleasant environment for passengers. This case study explores some of the areas that make use of such systems.

Networks

Integration

Computer systems have now been developed that integrate all areas of a modern airport. These areas (or modules) are linked via a network to powerful servers (see diagram below).

Integrated airport system



Brief description of each system

Air traffic control	Controls the air space around the airport including landing and take off.
Baggage system	Movement of baggage around airport.
Billing system	Calculates fees for the airlines.
FIDS	Flight information display systems.
Flight schedules	Flight details for each airline.
Ground services	Catering, use of buses, refueling, *etc.*
Handling agents	Airline check-in and other services.
Staff information	Airport staff information.

The complexity of the computer networks that manage modern airports can be seen by looking at some of the technical details for London Heathrow's Terminal 5 (T5), which opened at the beginning of 2008, and which was designed to handle up to 30 million passengers each year.

The high bandwidth backbone of the terminal's network contains over 2500 km of cable which connect two central data centres and 66 secondary communication centres. Over 9000 different devices are connected to the network which uses internet protocol (IP) to carry voice and data systems.[1]

A new control centre for the whole airport is also based at T5. This manages the movement of aircraft to and from the airport, communications with the airplanes' crews, and the movement of aircraft on the ground. The new control tower was planned to run in parallel with the old tower for three months before making the final switchover.[2]

All systems were tested for the six months preceeding the opening of the terminal with 16000 people recruited to act as "passengers".

Network security

Failure to secure the network from either accidental or deliberate errors could have a dramatic effect on the functioning of the network. If the different systems are integrated into one network, then care must be taken that a failure in one section does not have similar effects in other parts of the network.

Parts of the system are safety-critical, such as Air Traffic Control (see page 8). Even a failure in systems that are not safety-critical, such as baggage handling, could bring the effective functioning of the airport to a halt.

Airport networks must also be protected from potential dangers from the Internet, to which it will be connected through a gateway.

Various back-up systems must be considered. For example, some airports lay multiple fibre-optic links between the server room and the control tower so that the controllers would stay connected even if one line was cut.

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1 http://www.pcw.co.uk/computing/analysis/2187576/pilots-t5-technical-systems

2 http://www.airport-technology.com/features/feature916/

Airport security

Airport security can be separated into three areas:

- securing the perimeter of the airport
- security for the airport itself
- the security of each plane.

CCTV cameras are used extensively within airports, to monitor both the perimeter of the airport and the airport itself. Images are monitored by security personnel, and they can be stored digitally, and played back at any time. Some cameras can switch to infrared. Expert systems have been developed that attempt to recognize "unusual behaviour" within the airport buildings.

Employees

Every person that works within an airport, whether they are airport staff, employed by one of the many shops or restaurants, or airline staff, will require a security clearance to be able to enter any area within the airport. Each area can be "isolated" from the rest, requiring some kind of ID to be able to pass from one area to another. A device secured beside the access point or door will be able to verify the identity of an employee in a system.

These IDs could take the form of smart cards linked to some type of biometric identification system, such as:

- iris identification
- digital fingerprints
- hand geometry
- voice recognition
- facial recognition
- retina eye patterns
- signature identification.

Each system works by digitizing certain characteristics of the feature used, and storing these as a record for each individual on a computer system. Each security point in the airport will have a biometric device that could be a stand-alone system that compares the biometric data of the person with the data on the smart card. Alternatively, the device could be connected to a central database.

Fingerprint technology has been used for a long time and is consequently quite sophisticated. There are, however, ways to circumvent this system. Iris identification could offer a more secure system in the future, as it is difficult to forge, and is regarded as one the most accurate of the biometric technologies. It works by dividing an image of the iris into sections and turning the various patterns into mathematical expressions.[3]

[3] http://www.idlane.com/technology.htm

Passengers

Passengers are required to carry a form of identification (normally a passport) in order to board planes. For the airline, this matches the traveller with a particular flight reservation. For the security or immigration services, this determines whether or not the person will be allowed to continue with their journey. Modern passports are able to be scanned, allowing the passport data to be matched with data on the central database.

Airports are considering adding another layer of security with regards to the passengers. Consider the following article taken from *The Guardian* newspaper.

How tagging passengers could improve airport security

Friday 13 October, 2006
Alok Jha, science correspondent for *The Guardian*

Air travellers could soon be electronically tagged inside airports in a bid to improve security. The technology would use wrist bands or boarding passes embedded with computer chips and allow authorities to track passenger movement around terminal buildings.

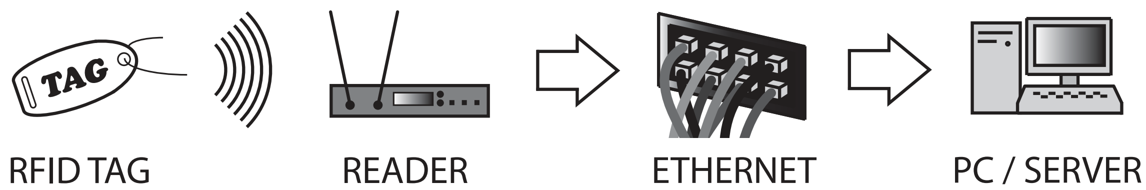
Paul Brennan, an electronic engineer at University College London who is leading work on the EU-funded Optag system, said it would combine high resolution panoramic video imaging with radio frequency identification (RFID) tags to enhance airport security, safety and efficiency. "It would work if each passenger were issued with a tag, which could allow location to about one metre accuracy," he said. "The video and tag data can be merged to give a very powerful surveillance capability."

RFID tags work by emitting a short radio message when interrogated by an electronic tag reader. Dr Brennan said that Optag RFID chips would not store any personal details.

"They emit a unique ID which is then cross-referenced to the passenger information already on the system – maybe the name and flight number of the passenger. Perhaps in the future that would be extended to things like biometric data." The tags would be linked to a network of CCTV cameras, which could be used to monitor movement of people around terminal buildings.

Dr Brennan said: "It can allow precise tracking of certain individuals if they seem to be a security risk of any sort. It can help to evacuate the airport. It can provide rapid location of lost children."

Optag could also ensure that passengers get to a gate on time to board aircraft. Dr Brennan said that flight delays due to late-running passengers cost airlines €100m a year in Europe. [4]



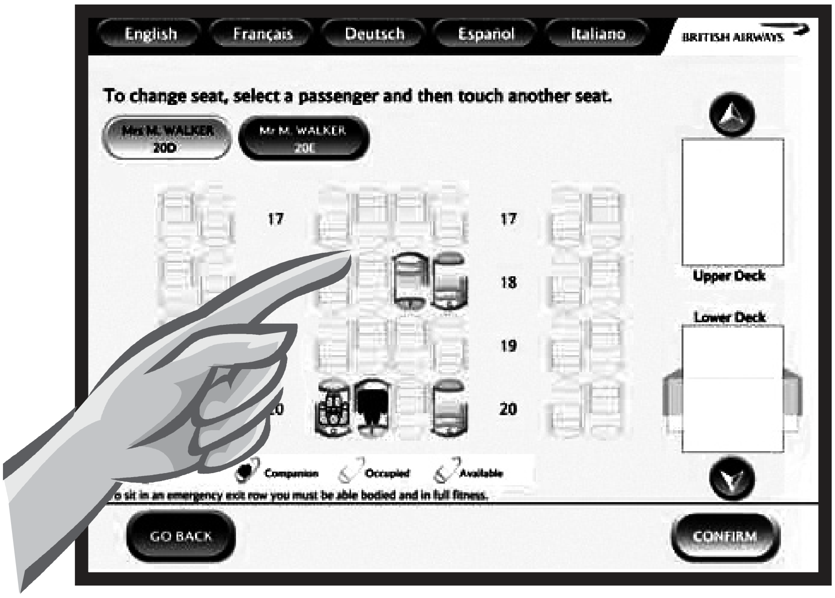
[4] *The Guardian* newspaper, Friday 13 October, 2006

Check-in

Airlines are looking for ways of using computer systems to help speed up the check-in process. Several airlines allow passengers to print their own boarding cards at home, allowing them to by-pass the normal check-in process at the airport, if they only have carry-on luggage.

Others provide self-service check-in kiosks, offering a quick, easy and safe alternative to traditional check-in desks. These self-service desks are computer terminals that are linked to the airline's computer system. They allow you to choose your seat and print your boarding card, or in some cases make changes to your travel schedule.

A self-service kiosk



[Source: Adapted from http://www.britishairways.com/travel/sscidemo7/public/en_gb]

Air traffic control

"Air traffic control (ATC) is a service provided by ground-based controllers who direct aircraft on the ground and in the air. A controller's primary task is to separate certain aircraft – to prevent them from coming too close to each other. Secondary tasks include ensuring safe, orderly and expeditious flow of traffic and providing information to pilots, such as weather and navigation information." [5]

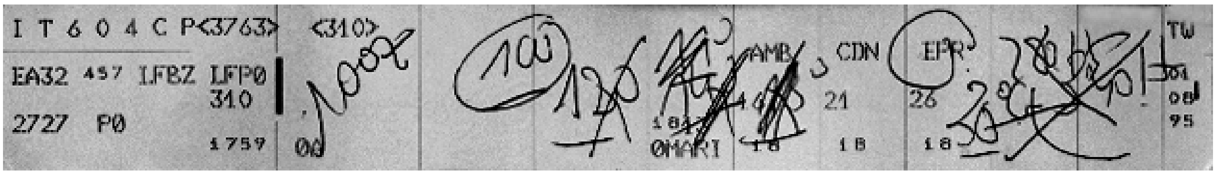
ATC will also update the flight details files in the main server, which will in turn update flight information display systems around the airport, and possibly trigger passenger announcements.

ATC has also seen the widespread integration of computer systems, primarily to allow increased traffic flow, whilst at the same time maintaining the same high levels of safety. This process, however, has raised an interesting question: can all (manual) systems be successfully computerized?

Air traffic controllers work in centres that control a certain area of air space. They deal with aircraft that enter that space by monitoring the position of the aircraft using radar, and maintaining contact with the pilots by radio. Whenever an aircraft enters their air space, a computer prints off a strip of paper which contains details of that aircraft (type, departure/arrival airports, flight number, ID number, *etc.*) and their flight plans (speed, course, altitude, *etc.*).

A controller, on hearing the printer, will take this strip and place it in front of him with other strips representing the aircraft that are his responsibility. As each aircraft passes through the sector, the controller will regularly annotate each strip by hand, indicating, for example, changes of height, control passed to another centre, *etc.* A strip will typically end up with many annotations, all made by hand. He will also change the position of the strips grouping together aircraft that are close to one another, or arranging them in groups depending upon which sector they are in. When aircraft pass out of their control (for example, when they have landed), the relevant strip is removed.

An example of an annotated flight strip is shown below:



[Source: http://perso.tls.cena.fr/chatty/biblio/CHI96/sc_txt.htm]

A great deal of money has been spent in developing software that would replace the paper strips, but many controllers remain reluctant to change a system that has proven so reliable in such a safety-critical area as flight control.

"Air traffic controllers like paper flight strips. The interface is familiar, easy-to-use, helps controllers instantly understand the current state of the traffic and lets them communicate without interrupting each other." [6]

In particular, they are concerned that manipulating a computer-user interface will distract them from their tasks, and that important data automatically updated on a computer screen will go unnoticed.

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[5] en.wikipedia.org/wiki/Air_traffic_control

[6] Wendy E. MacKay, University of Aarhus

Baggage handling: Software design

The main function of a baggage handling system is to transport bags quickly from a baggage entry point (*e.g.* a check-in desk) to a pre-determined output point (*e.g.* into a container for loading onto the aircraft). Parts of the system life cycle for the design of the baggage system for London's Heathrow Airport (Terminal 5) are outlined below.

Requirements specifications

Specifications had to be agreed between the two major stakeholders, the company that runs the airport (British Airports Authority), and the airline that would exclusively use the new terminal (British Airways).

Between the bag entering the system and arriving at its destination within the airport, several processes could be applied to the bags. These include bags being:

- automatically identified by their bag label
- screened for explosives (by automatic in-line hold baggage screening machines)
- stored in an early bag store (if passengers are too early for their flight)
- manually encoded (for resolving problems with bag information)
- sorted to flight allocated loading positions (automated sorting)
- fast tracked (for late bags that require urgent processing)
- manually handled (for large bags; and loading and unloading systems)
- reconciled (checked to see if bags are authorised to load onto aircraft *e.g.* to avoid a bag travelling without its owner).[7]

Development problems

Potential problems involved:

- the use of many different suppliers
- the use of a completely new design
- the length of the project, which had a life-cycle of 7 years, which meant that specifications could change.

Testing

As the system will be in operation for 24 hours a day, it is essential that extensive testing takes place before installation. This testing includes the use of 3D virtual reality baggage handling simulators.

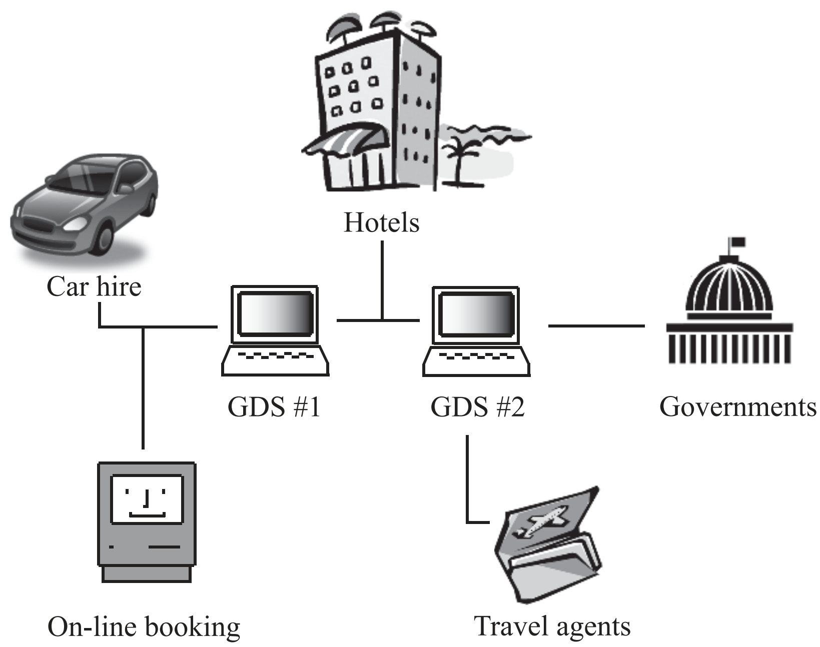
[7] http://newsweaver.ie/qualtech/e_article000776781.cfm?x=b11

Reservation systems

When a customer makes a flight reservation a unique "passenger name record" (PNR) is created, which contains flight information and personal details of the person flying. If a car is hired or a hotel is booked at the same time, this information will also be stored on the PNR.

Few airlines store these records on their own system, but instead subscribe to a "global distribution system" (GDS), which is an organization that stores flight details and PNRs for several airlines on its databases. At present, there are four major GDSs: Amadeus, Galileo, Sabre and Wordspan. Travel agents are connected to these GDSs through Wide Area Networks.

Various sources contribute to a PNR record



These GDSs use a similar format for their records so that information can be passed between them. This allows computerized reservation systems to book flights using one or more airlines with minimal delay. In recent years, certain governments have requested that more detailed personal information is added to a PNR. Agreement has been reached, to the alarm of human rights organizations, that the information on these records can be accessed by governments and used to fight certain serious crimes.

A PNR could, therefore, contain credit card details, addresses, phone numbers, emergency contacts, information on people who travel together, personal preferences (such as meal choices), details of medical conditions and so on.

Passenger services

Displays

Information is transmitted to passengers either via screens (flight information display systems) or by means of public announcements.

ARRIVALS Date: Jul 29 Time: 11:38:00

FLIGHT No.	TIME	FROM	FLIGHT INFORMATION	
RE 311	11:30	DUBLIN	LANDED	11:28
GR 067	11:35	GUERNSEY	LANDED	11:35
EZY 359	11:50	GLASGOW	EXPECTED	11:55
FCA 101	12:10	RHODES	DELAYED	12:55
KL 227	12:22	AMSTERDAM	EXPECTED	12:28
OL 863	12:56	HAMBURG	DELAYED	13:43
EZY 797	13:12	MALAGA	EXPECTED	13:14
SN 257	13:20	BRUSSELS	EXPECTED	13:20
AF 263	13:35	PARIS		
EZY 179	13:42	EDINBURGH		
EZY 479	13:48	VALENCIA		

Mr Wallace meeting Mr Jones on Flight EZY 359 from Glasgow
Please go to the Airport Information Desk

Each flight is automatically categorised as either arrival or departure, and included on the appropriate set of pages with a choice of arrivals or departures on each individual public screen. Displayed information includes: flight number, airport name, scheduled time and expected time, and status (on-time, expected, landed/departed).

Flight records are sorted according to the same criteria as the ATC displays (*i.e.* expected movement time) and removed from the display a few minutes after the flight has been shown as "landed" or "departed", which occurs when ATC enter an actual movement time for the flight.

Announcements

Traditionally, airport announcements were made using recordings of actual voices. This inevitably led to awkward sounding messages, as different phrases were "patched" together. Problems would occur if new airlines or new destinations arose, as new recordings would have to be made (with, perhaps, different voices). Over the past few years, companies have been developing new automated systems that do not rely on actual voice recordings.

The system developed for Heathrow Airport works by generating and storing the individual phonemes (sounds) that make up a particular language. The phonemes depend, not only on the arrangement of letters within a syllable but also on the position of the words within a sentence, and the words appearing immediately before and after it. The word "passenger" for example, has 36 phonemes associated with it.[8] The system is being linked to the flight information display system at the airport, so that announcements can be made dynamically in real time. The system was introduced in two phases. The first dealt with general passenger announcements in the different terminals. The second phase was introduced at the different boarding gates, and allowed individual PCs to generate local announcements.

[8] http://www.airport-int.com/categories/airport-terminal-announcements/its-phonemenal.asp

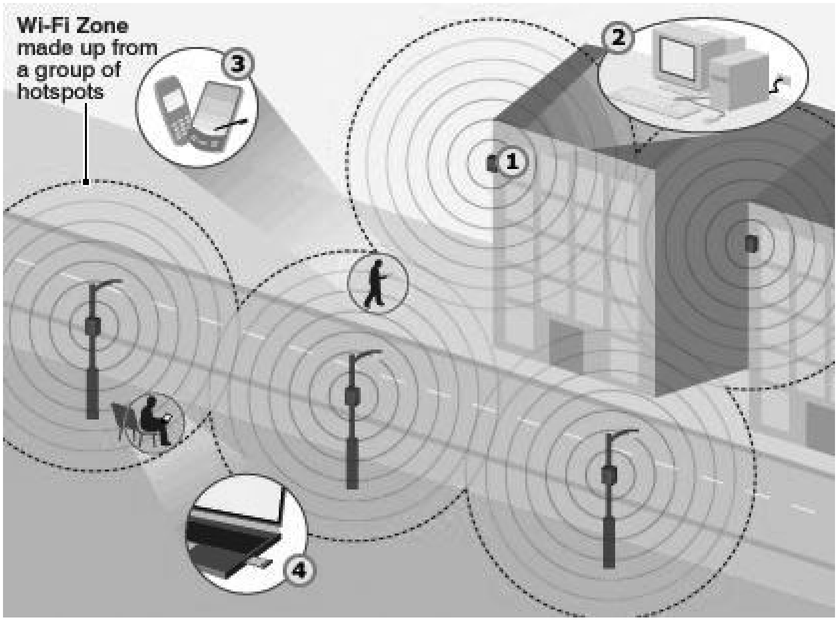
Wi-Fi

Most airports now provide Wi-Fi "hotspots" which allow users to connect their laptops to the Internet. In order to connect, users have to enter their username and password. These are given once the service has been paid for (using vouchers, credit cards, *etc.*).

Wi-Fi originally used "wired equivalent privacy" (WEP), which is encryption technology designed to secure the data being transferred between the transmitter and the user's laptop. However, this technology was shown to be easily broken. One method was to "trick" the user's laptop into thinking that it had logged onto a secure network, when it had not. It did this by exploiting the basic hand-shaking system.

An improved security system, "Wi-Fi protected access" (WPA2) is now available, which has shown itself to be very secure. However, it is still recommended that the service provider makes use of strong passwords.

Wi-Fi is a global set of standards that use a radio frequency of 2.4 GHz (the same as mobile phones) with a range up to 100 metres. Transfer rates, by 2008, had reached 11 Mbits/s.



[Source: http://www.bbc.co.uk/news]

Is there an overdependence on computer systems?

This case study has demonstrated how computer systems are now at the heart of all areas of a modern airport, and are helping to make air travel safer, more efficient, and more pleasant for the thousands of passengers who pass through these airports.

It is, perhaps, inevitable, that as technology develops, such systems become more and more complex, and it is this very complexity which can, at times, cause problems.

In August 2007, the computer system used by the US Customs and Immigration Service malfunctioned at Los Angeles International Airport. This resulted in over 20 000 passengers being stranded at the airport for several hours awaiting clearance to enter the country.[9]

In July 2008, a faulty network card caused the US$100 million radar system at Ireland's Dublin airport to malfunction, causing delays for several thousand passengers.[10]

We often hear of systems being affected by hackers or unhappy employees, but the culprits for the two problems outlined above (and for many others) were the systems themselves.

The more complex a system is, the more ways there are for it to go wrong and the longer it will take to be fixed. As we become more and more dependent on computer systems, not just in airports but in all areas of our lives, the consequences of failure become increasingly severe.

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[9] *The New York Times*, 12 September 2007

[10] http://www.irishtimes.com/newspaper/breaking/2008/0717/breaking73.htm

Appendix I – Abbreviations used in the case study

3D – 3-dimensional

ATC – Air traffic control

CCTV – Closed circuit television

EU – European Union

FIDS – Flight information display system

IP – Internet protocol

T5 – Terminal 5 (London Heathrow Airport)

PNR – Personal name record

RFID – Radio frequency identification device

WEP – Wired equivalent privacy

Wi-Fi – Wireless fidelity

WPA – Wi-Fi protected access

Appendix II – Bibliography

Air traffic control.
URL: http://en.wikipedia.org/wiki/Air_traffic_control

Airport Security.
URL: http://www.saic.com/aviation/security.html

Banks, J. *T5 – We Have the Technology*. 1 February 2007.
URL: http://www.airport-technology.com/features/feature916/

The Brain in Spain.
URL: http://www.airport-int.com/categories/artificial-announcement-systems/artificial-announcement-systems.asp

Derksen, R. van der Wouden, H. and Heath, P.
Testing The Heathrow Terminal 5 Baggage Handling System – Before It Is Built. 3 April 2007.
URL: http://newsweaver.ie/qualtech/e_article000776781.cfm?x=b11,0,w

Duffy, J. *The future of airport security*. 12 November 2003.
URL: http://news.bbc.co.uk/2/hi/uk_news/magazine/3263343.stm

Faulty computer blamed for airport radar breakdown. 17 July 2008.
URL: http://www.irishtimes.com/newspaper/breaking/2008/0717/breaking73.htm

Friedlos, D. *BA pilots T5 technical systems*. 12 April 2007.
URL: http://www.pcw.co.uk/computing/analysis/2187576/pilots-t5-technical-systems

Gibbs, W. (September 1994), "Software's Chronic Crisis". *Scientific American*. **271**, pages 72-81.
URL: http://www.cis.gsu.edu/~mmoore/CIS3300/handouts/SciAmSept1994.html

Godin, J. *It's Phoneme-nal*.
URL: http://www.airport-int.com/categories/airport-terminal-announcements/its-phonemenal.asp

Hasbrouck, E. *What's in a Passenger Name Record (PNR)?*
URL: http://www.hasbrouck.org/articles/PNR.html

Jha, A. *How tagging passengers could improve airport security*. 13 October 2006.
URL: http://www.guardian.co.uk/business/2006/oct/13/theairlineindustry.terrorism

Leake, J. *Chaos continues at Heathrow's T5 as more flights are cancelled*. 29 March 2008.
URL: http://www.timesonline.co.uk/tol/news/uk/article3645398.ece

Mackay, W. (2000), "Is Paper Safer? The Role of Paper Flight Strips in Air Traffic Control". *ACM/Transactions on Computer-Human Interaction*. **6 (4)**, pages 311-340.

Passengers stuck in planes after computer fails. 12 August 2007.
URL: http://www.cnn.com/2007/US/08/12/LAXBackup.ap/index.html

Ranganathan, A. *Fog and the air traffic chaos*. 27 December 2006.
URL: http://www.thehindubusinessline.com/2006/12/27/stories/2006122700070900.htm

Schwartz, J. *Who Needs Hackers?* 12 September 2007.
URL: http://www.nytimes.com/2007/09/12/technology/techspecial/12threat.html

Stevens, T. *The cost of privacy: biometrics at London Heathrow T5*. 24 March 2008.
URL: http://www.computerweekly.com/blogs/the-data-trust-blog/2008/03/the-cost-of-privacy-biometrics.html

Technology.
URL: http://www.idlane.com/technology.htm

Valdes, M. *Alaska Airlines, Sea-Tac Airport look to streamline check-in*. 10 August 2007
URL: http://seattletimes.nwsource.com/html/travel/2003830033_alaskaairweb10.html

Vancouver Airport.
URL: http://www.alstec.com/Main/ALSTECGroup/AirportsLogistics/CaseStudies/VancouverAirport/

WiFi at the Airport.
URL: http://www2.prg.aero/en/site/klient/sluzby_kontakty/komunikace/wifi.htm

Wi-Fi security system is "broken". 19 October 2007.
URL: http://news.bbc.co.uk/2/hi/technology/7052223.stm