The Internet of Things and e-Enablement has the potential to analyse in detail hundreds of elements of an airline's business operations. The results of this analysis can thus be used to extract efficiencies in a large number of aspects, and so deliver substantial savings.

Applying e-Enablement & big data analytics to techniques flight operations

Several hundred business or operational factors determine an airline's efficiency. Most of the main factors can be grouped into the categories of: flight operations and aircraft fuel burn; maintenance and engineering (M&E); ground operations; revenue generation and management; airline overheads; and passenger services. There can be several hundred factors in each category.

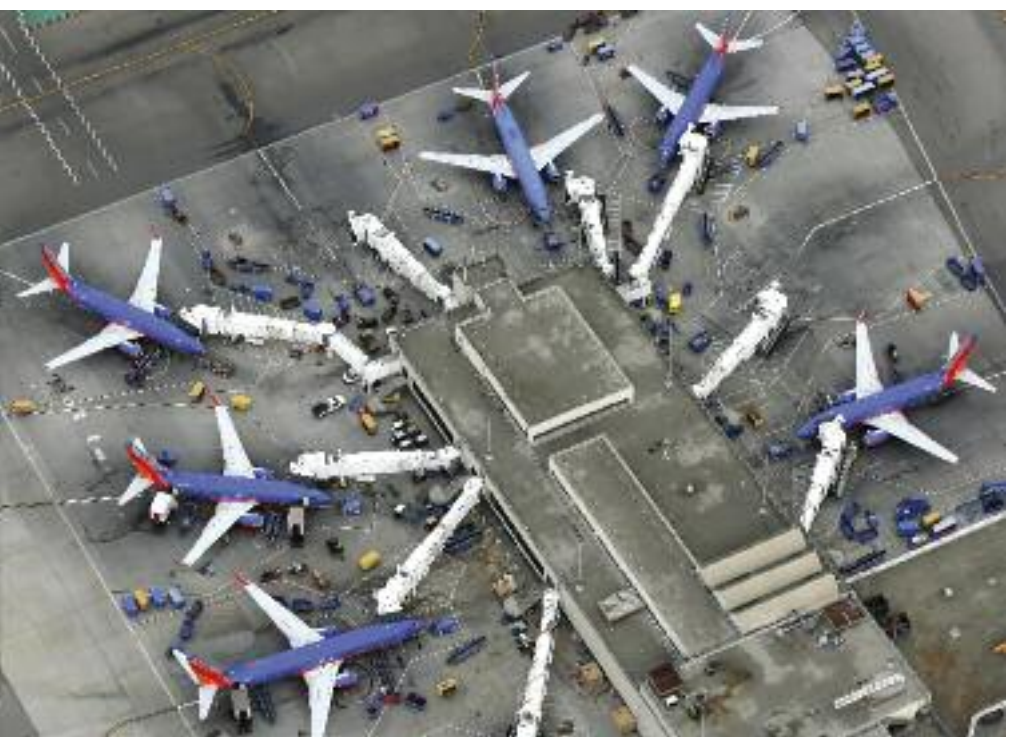
Easy efficiency gains

Until the past few years, airlines have only been able to improve efficiency and achieve long-term cost reductions by tackling a small number of these factors.

There are several examples of long-term improvements achieved by airlines in M&E. Savings have been realised by extending fixed maintenance intervals, increasing on-wing removal intervals for engines, improving the reliability of components, and digitising aircraft and engineering documentation.

Within flight operations, savings in fuel burn have been achieved through: aircraft weight reduction programmes; post-flight analysis of the main factors that affect fuel burn such as track used; and small changes to operational procedures, such as reduced use of thrust reversers at landing and continuous descent approach.

In passenger sales, airlines have reduced costs and/or improved efficiency by: reducing the overall cost of sales; increasing the percentage of tickets sold direct rather than through third parties; increasing load factors; and simplifying fare structures. They have also increased marketing power and reduced ground-related costs, especially if they are a member of a large airline alliance, and reduced passenger handling and ground-related charges through self-service kiosks and mobile apps for use by passengers.



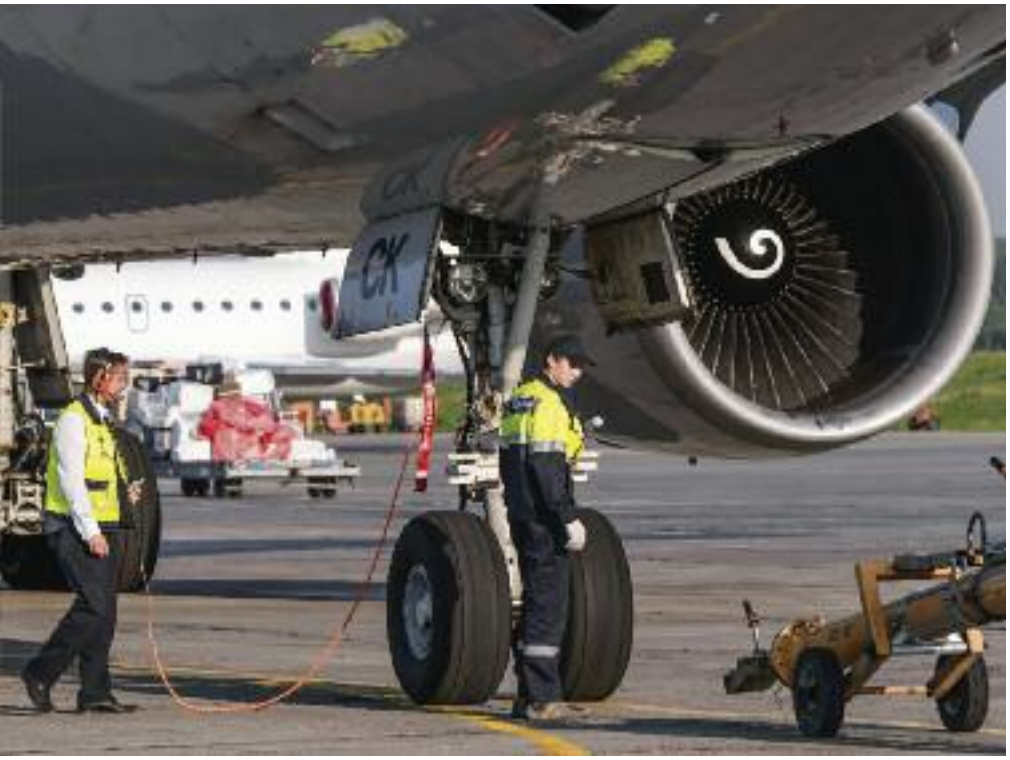
Prior to the advent of e-Enablement and big data analytics, airlines were only able to address the easiest of high cost of low efficiency issues. One of the first areas of an airline's activities to benefit from e-Enablement is flight operations.

Efficiency gains in detail

While all airlines have generally been able to make efficiencies along these lines, the main drawback is that they have only been able to deal with a minority of the factors in their organisation and business operations that affect efficiency. Moreover, they have not been able to target operational efficiencies and costs in detail, because it has not been possible to monitor most elements that affect operational efficiency, or take action to improve them.

A particular example is the aircraft turnaround process, and the time it takes. Dozens of factors affect turnaround time, including: the availability of all the different aircraft servicing trucks and vehicles and their associated staff; time to service the aircraft and cleaning; airport gate availability; time required for routine line maintenance; the known quantity of fuel that has to be loaded onto the aircraft; time to call the refuelling truck; time to refuel; time required to offload and load baggage; time to load water and service lavatories; and others.

In turn, several factors affect each of these issues. There is the added



The aircraft turnaround process includes many elements, some of which are inter-dependent. To gain a significant reduction in the time used in the aircraft turnaround process, all elements need to be analysed in detail. Only e-Enablement and big data analytics, with the right algorithms for processing, can achieve this.

complexity that some of these factors are inter-dependent, particularly the time it takes to refuel. The first requirement is that the amount of fuel needed on the aircraft has to be confirmed, which information comes from the flight dispatch department. It can take some time for the amount of fuel required to be known, and it may also be adjusted several times. The availability of the airport refuelling truck will depend on the total number of trucks available and aircraft refuelling activity at the time.

Analysing all the hundreds of factors and relationships in the aircraft turnaround process has not been possible until the past few years. Detailed data were unavailable for each one of the hundreds of factors, and it was not possible to process and analyse all the data from thousands of flights within an airline's operation and understand why particular actions and activities take the time they do.

This problem of being unable to analyse every aspect of an airline's operation in detail is repeated for hundreds of other elements within the business.

The problem in recent years with the traditional system of achieving greater efficiencies in the various airline processes is that diminishing, or even negative, returns, may have been reached. This has been through point solutions, which often have a high initial cost compared to the returns they generate.

Examples are where IT systems and processed data have been used to analyse particular operating procedures and post-flight data. The results of the analysis have been used to show, for example, how a certain operating technique can be used to reduce fuel burn. This can be through techniques such as engine-out taxiing, non-use of reverse thrust at landing, continuous descent approaches, carrying a smaller amount of potable water, and using the auxiliary power unit (APU) for a shorter time when on the ground. "The issue here is that it requires one or several staff members to analyse the post-flight data over an extended period. This incurs the cost of employing at least one person, plus the associated costs of employment," says Michael Bryan, principal and chief executive officer at Closed Loop Consulting. "This has to be compared with the savings that can be made from each of these fuel-saving techniques. Each technique can save only a small amount of fuel, while not all of the techniques can be performed simultaneously on the same flight, and some cannot be used on every flight.

"The main weakness of analysing data using traditional software, such as Excel spreadsheets, is that it does not provide enough detail," continues Bryan. "The industry needs the ability to analyse most elements of an airline's operation in detail to realise true gains in efficiency, rather than doubtful or marginal ones."

IoT and e-Enablement purpose

Monitoring every element of an airline's operation, processing data, and changing many of the elements is achieved through e-Enablement and the Internet of Things (IoT) for aviation.

Traditional airline processes have been steadily simplified and automated over several decades by the gradual growth of autonomous, departmental IT systems. The first disadvantage of this, however, has been the high cost of developing, installing and implementing these IT systems. These processes still require some manual intervention, are prone to human errors, and it takes a long time to accomplish all the data transfers and processing steps.

Airline IT systems also do not interface with other departments and groups in the same airline. Data can be in different formats and standards across airline departments and IT systems. IoT is the process of linking all devices and desktop computers, all aircraft and associated assets in the airline's fleet, and all electronic flight bags (EFBs) and electronic technical logs (ETLs) together and through the internet and a data processing platform. The IoT thereby circumvents the problem of autonomous, legacy IT systems operating with different formats, and also negates the need for an airline to create a company-wide IT system.

E-Enablement is the process whereby the data that has been taken from and transferred between all devices, via the internet, is automatically transferred to a Cloud-based server, standardised and processed, and then automatically transferred to another device and department for use. The IoT and e-Enablement process operates on data in an internet protocol (I.P.) format. One main difference between a single platform and a range of point solutions is that the single big data analytics platform provides a better rate of return.

Data in the server and data platforms are processed automatically using algorithms. These are designed and configured so as to provide a particular type of data or information. Since large volumes of data are being processed it has been termed Big Data Analytics.

This is the core of the e-Enablement process. The algorithms are used to generate particular data analysis or usable information. The concept of e-Enablement is that all operational data is processed to quickly provide all parts of an airline's operation with actionable intelligence so that it can be used effectively. Using a previous example, passenger numbers and checked-in baggage weight can be sent to the flight dispatch department. This will allow small adjustments to the fuel load on the flight plan. This information could also

be transferred at high speed to the flightcrew via their EFBs, as well as to the refuelling truck, resulting in fuel savings. All this processing and data transfer would take too long with legacy IT systems for the data to be useful.

A large volume of data is generated by the aircraft, the EFB/ETL ecosystem, and the M&E department. Modern aircraft provide data from thousands of different sources via sensors on thousands of operational and performance parameters. The connections between aircraft, processing facilities, and airline departments are expanded exponentially by the IoT.

The IoT and e-Enablement create the ability for systemwide information management (SWIM) across the majority of an airline's departments, or even its entire operation. It is not yet clear what the magnitude of the expected or actual benefits of e-Enablement will be, however. Airlines are still at an early stage of implementing the IoT and becoming e-Enabled. It is likely to continue evolving for another 20 years before it approaches maturity.

"While the concept of the IoT and e-Enablement looks and sounds appealing, it will actually only work if it looks in detail at the right issues. A good example is the technique of engine-out taxiing after landing," says Bryan. "This is not always possible at particular airports because of high-gradient taxi ways, or it is possible but requires such a high thrust rating from the engine or engines that are operating so as to cancel any fuel saving that would be realised on a level taxi way. To analyse at which airports and on which occasions this, and other operating techniques, can really achieve a saving requires a large number of other details to be analysed. In this example, these include the slope information of taxi ways at each airport, plus other details, such as the engine thrust rating required at taxi, and the related fuel consumption. In other words, to calculate any real or possible saving requires the power of big data analytics. It is not as simple as this, however. The result achieved is only as good as the analysis of the data and the content of the algorithms written. Not only is detailed analysis required, but it needs to have the correct quality."

In-service e-Enablement

The IoT for Aviation and e-Enablement are general phrases being used by many to describe the potential future SWIM-style of data processing across an entire airline. No airlines have achieved full e-Enablement. M&E IT systems and content management systems (CMSs) have been developed for the past 20 years, and have specialist functionalities. Revenue management (RM), reservations and all the related passenger sales processes also have specialised IT systems and dedicated infrastructure. Airline management functions, particularly human resources (HR) and finance, are operated via enterprise resource planning (ERP) systems. It is unlikely that airlines will attempt to transfer all functions and data processing activities into a single e-Enablement system immediately.

Despite the common use of the terms IoT and e-Enablement, several vendors have developed platforms to process and transfer data between different nodes in an airline for sections of its operation. Some of these relate to the airline's flight operations.

Global Eagle Entertainment (GEE) has developed one such platform, and has had this in operation with its first customer airlines for five years. "A large number of sensors need to communicate with a central platform that analyses and processes the data that it has received," says Bernard Asare, vice president of operations solutions and data analytics at GEE. With all nodes connected to the right devices, it is possible to get a lot of passenger behaviour and aircraft data to the servers for fast analysis and processing so that it can be used to maximum advantage.

"GEE acquired NavAero, which manufactures EFB hardware and associated equipment," continues Asare. "One of NavAero's products is the universal aircraft interface device (UAID). The UAID gives an airline the capability to connect EFBs, which operate on I.P., and their hosted apps to the satellite communication (Satcom) system and the aircraft's flight management system (FMS). The UAID also connects to the ARINC 429 and ARINC 717 databuses. These databuses store a lot of operational data, including FMS data, that is transmitted via the aircraft's ACARS system, as well as safety data that relates to the actual flying of the aircraft.

"The UAID is used to transfer data from the various avionic units into I.P. format, and share it with the apps on the EFBs that work in I.P.," explains Asare.

"The UAID also interfaces with the satellite management unit. All data from the avionics and the EFB can be transferred to the ground in I.P. format, which is required as the common format for the e-Enablement process. The UAID also interfaces with the aircraft's WiFi and 3G/4G on-ground connectivity systems, which are used to transfer large volumes of I.P. data post-flight."

GEE has primarily been an in-flight entertainment (IFE) system vendor. It provides airlines with an on-board server that hosts IFE content. Analysis of passenger data relating to IFE use and choices is important, since it can provide a detailed insight into the airline's return on investment in IFE systems and content.

Data from both the aircraft's avionics, EFB devices, flight operations departments, and IFE servers on the aircraft can all be transferred to GEE's ground-based secure Cloud. "This is called the Masflight Analytics and Intelligence Platform," says Asare. "The Cloud aggregates the information off the aircraft, as well as collecting it from multiple ground sources. This includes systems providing information on flight schedules, the status of flights in progress, flight tracking information, weather, airport gate information, taxi times, and an array of information from operations and maintenance control departments."

GEE has also developed an app called Air View Operations Connect. "This provides situational awareness for the connected fleet for use by the operations department," says Asare. "Many hundreds of aircraft factors are monitored through the app, including aircraft position, time of arrival, fuel on board, the number and identity of crew members, aircraft registration, and many other details.

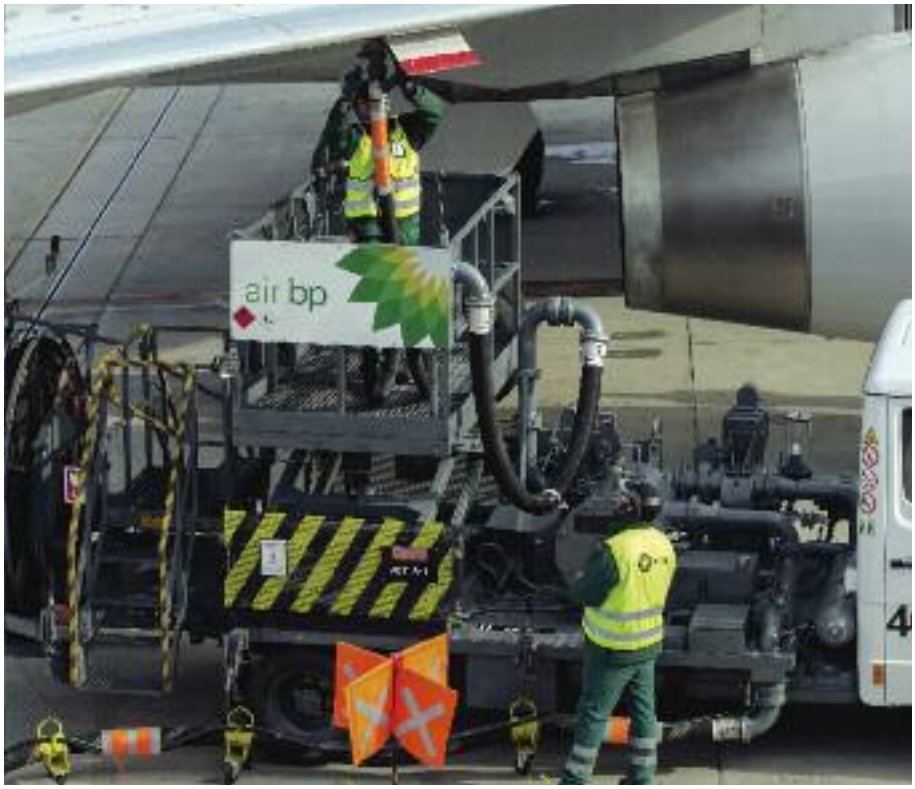
"The data are processed for many different reasons," continues Asare. "Some of these are post-flight analysis with the aim of achieving longer-term efficiency improvements. Others are an immediate processing and analysis for same-day operations. One particular issue we are interested in is getting a large quantity of passengers' demographics, and their behaviour with respect to IFE choices and shopping."

GEE's servers and data-processing functions can analyse passengers' entertainment preferences to see how many use the IFE system, and of those that do, how many are interested in audio or visual content, games, magazines, shopping, and social media. This allows airlines to trim costs by avoiding content that has weak demand.

"The UAID on the aircraft is one node in the IoT/e-Enablement network that allows a large percentage of data to be acquired for an airline's overall operations. That is, the aircraft and engine fleet, the EFB/ETL ecosystem, and on-board passenger behaviour," says Asare. "We then use the internet to transfer these data to our server for analysis and processing."

The Cloud infrastructure is where the data are processed and analysed. "There are multiple providers for Cloud-based data processing and we use Amazon," says Asare. "Over the past five years we have built a system designed to ingest data from multiple sources and nodes in the airline's operation, store and process it. The Cloud server then feeds the business apps in the airline's operation so that the maximum value can be extracted from it. Once all this is in place, we require the airline to build a series of dashboards, so that each one can monitor all the factors relevant to the particular part of the airline's operation. Our system architecture also makes it possible for airline user staff to access data on a desktop computer via custom-built application programming interfaces (APIs)."

GEE started building the system in 2009, and it has been in service for three to four years. To date, GEE has secured 27 airline customers, including: Southwest, United, American, Spirit,



As an example of one element of ground operations and the aircraft turnaround process, improving the time taken and the accuracy of aircraft refuelling is something that requires detailed analysis and can yield savings and efficiency gains.

Alaska, jetBlue and Frontier in the US; and Norwegian, Icelandair and Fly Dubai. "Due to acquisition of other companies, we have been able to get into several aspects of an airline's operation," says Asare. "GEE mainly focuses on airline operations and passenger behaviour, especially with respect to IFE usage. We have not ventured into other areas of an airline's overall operation, such as RM and passenger sales, M&E, or general management. These areas are already covered by specialised systems. We therefore do not provide a total IoT and e-Enablement system for an airline, but instead just cover the major element of flight operations and also analysis of passenger IFE utilisation. It is conceivable, however, that the scope of our platform and other similar products will gradually be expanded over time."

Examples of the way it is used by airlines include: getting real-time intelligence on fuel consumption; and tracking aircraft, so as to acquire detailed information on flights such as accurate arrival times and air traffic control (ATC) overflight charges. There are also are a number of user cases. Many of GEE's airline customers focus on flight operations. "They need to have a real-time pulse on on-time performance across the fleet and operation, so there is a dashboard to monitor," says Asare. "Another interesting and useful function is to make comparisons of different airlines' operating schedules. GEE's platform can monitor the optimum departure and arrival times for each route from an operational perspective. That is, timetables to avoid the delays and other issues or problems that cause interruptions on a regular basis. The system can also be used to plan aircraft turnaround procedures and operations. This is analysed at a detailed level, as described. The system's algorithms and analytics capabilities are able to identify inefficiencies in many elements of an airline's operations through granular analysis. It can also monitor and analyse the ripple effects of severe delays, and so provide the operations department with information to allow it to make contingency plans. The system can also analyse aircraft utilisation, and improve schedules, turnaround times and other aspects to achieve the optimum aircraft utilisation. Overall, the process transforms an airline's ability to analyse all of the thousands of factors that affect its economic and operating performance at a very detailed level."

Asare explains that one big issue with this capability is whether airlines can build apps to acquire the data that they want from the aircraft and its various systems.

Airline operations

In addition to GEE, I-Jet Technologies has developed a specialised platform to analyse and process airline fleet and aircraft operational data. "Airlines ultimately want to improve the efficiency of hundreds of parameters," says John Schramm, chief executive officer at I-Jet Technologies. "Our system is designed to help airlines throughout the entire cycle of each flight. This includes the pre-flight and pre-departure phase. Prior to e-Enablement and data analytics, airlines had no information about an aircraft's status except for flight crew reporting it verbally over short-range radio or by filling in paper forms and handing them to ground staff. With the right sensors on the aircraft, a lot of information on its status can be transmitted in real time to the operations centre, including on fuel in the tanks, the amount of potable water on board, doors open or closed, APU running or off, and so on.

"Our system, which is called the I-Jet Technical Data Access Platform, focuses on an array of aircraft status and operational parameters," continues Schramm. "These include weight and balance data and information, position of aircraft controls, and engine parameters,. The platform is also designed to analyse flight operation performance. It can therefore compare planned and actual trajectory; and analyse distance, time, wind component and fuel consumed."

Another feature of I-Jet Technologies' platform is the analysis and diagnosis of in-flight technical faults and maintenance issues. "The system can interrogate the aircraft's operational data storage systems, and stream maintenance data for analysis for the 10 minutes before an event such as a fault to the platform," says Schramm. "The system will then analyse the cause of the problem."

It is also possible to download fuel efficiency parameters in real time for the relevant departments in the airline's organisation. These data can be integrated with the fuel efficiency systems and applications. Another feature that I-Jet Technologies is looking at is in-flight turbulence and reporting. Eddy dissipation rate (EDR) is a measure of in-flight turbulence, and I-Jet Technologies is now looking at using the platform to collate EDR data from airline fleets while in flight. I-Jet Technologies will process it and provide a turbulence information service.

"We are also looking to improve the aircraft arrival service," says Schramm. "The crucial element for this is providing an accurate time of arrival. There are often large differences between the actual time of arrival and the expected time that the flight operations department has. This difference is often the cause of airport terminal gates not being available."

I-Jet Technologies is also using its platform to monitor CO2 emissions, and collate this with accurate fuel consumption data for airlines. "The

One aspect of business processes that is important to airlines is managing passenger behaviour. Airline apps hosted on mobile phones and smart devices make it possible, with passengers' permission, to monitor their movement through the check-in and departure process. Data processing platforms are also used to monitor passengers' buying behaviour and entertainment choices via the IFE system.

system can track the aircraft's longitude and latitude positions throughout each flight," says Schramm. This can then be used to identify the distance flown over each country's airspace. It is necessary to calculate this because airlines are charged for CO2 emissions by each country according to the number of miles flown in their airspace. The rates for each country vary, so airlines want accurate data. The same applies to air traffic control (ATC) charges. These can also be monitored accurately if the system provides better situational awareness of the aircraft for each flight.

Passenger experience

As described, GEE's system can be used to provide detailed analysis of what audio, visual and other content passengers like, as well as what shopping products they prefer, and what adverts they respond to.

"As an IFE system supplier, GEE already has an insight into the IFE market and what the main products are, and which are generally in the highest demand," says Asare. "The full capability to analyse passengers' behaviour with respect to IFE choices has come together over the past two years. One set of analytics, for example, can provide granular information on how effective particular adverts displayed on the IFE system are, or which particular ancillary revenue products are the highest sellers."

One particular area of interest in analysing passenger behaviour is the ability to monitor passengers' physical movements. This is now possible via the use of airline apps hosted on passengers' mobile phones and smart devices. With a passenger's permission, an airline can track their activity, including their physical location within the airport terminal.

This will not apply to all passengers, since not all will have the app or a smart device, and not all those that do will give the airline permission to track them. The same capability can also be used to monitor passengers in close proximity to the airport. This can provide useful information for issues such as monitoring the possibility of no-shows, or if a large number of passengers is experiencing delays getting to the airport.

Overall, this capability will help to minimise delays, and avoid revenue leakage through no-shows. If data on each passenger's behaviour are collected over the long term then patterns can be detected. Examples are a person's particular preference for certain goods when shopping on board, and particular drinks or food in business-class lounges, or on-board. The implications of passengers' activities can be used by other departments. Examples are airline operations switching aircraft types on a particular flight following sudden and short-term changes in demand, altering ground-servicing activities, and changing the catering being loaded onto the aircraft before a flight.

IoT & e-Enablement

The process for setting up airlines with the IoT for aviation and being e-Enabled involves several stages. "The IoT for aviation is really the use of a large number of the next generation of sensors on many aircraft, engine and component assets; as well as computers and devices," says Wayne Enis, director of sales engineering, at Flatirons Solutions. "The key is that the sensors make use of a common data specification. This has been coupled with a broader range of sensors. The data can also be transmitted in both directions, so data do not just travel from the sensor to the processing platform, but also from the platform to sensors located on components. This is so that the action of the sensor or the component it is attached to can be influenced."

For an airline to get set up with the IoT involves creating hardwire connections between the various devices and assets with the internet. "It is a case of channelling the data into a central repository or a data platform," explains Enis. "In practical terms there are some complex steps, and this involves establishing all the physical connections and data feeds."

Bryan at Closed Loop Consulting, explains that the IoT for aviation is effectively already set up. "All that an airline has to do is harvest and channel the data that is already provided."

The airline has to organise this process of collecting all possible streams of data and feeding them, via the internet, into the central processing platform that it has chosen. "While some large airlines, including Emirates, which has a big IoT and data processing initiative, are organising this process themselves, there are consulting firms that specialise in setting up the IoT for airlines. These include providers such as CAP Gemini and Accenture," says Enis.

The airline only has to feed the data streams into the processing platforms via the internet. "The core of establishing this capability is generating specialist data analytics tools. These may be produced by the airlines themselves, or created by specialist providers," says Bryan. "The amount of data that can now be processed is so large that people are talking about data lakes, seas and oceans. The data repository and processing platforms can be created in several ways. This includes developing them in-house, using specialist platforms that include algorithms from vendors such as GEE and I-Jet technologies, or through large big data analytics platforms that are available from large IT vendors; which include Predix from General Electric.

"The big issue with the IoT is to pay a specialist data company to process the large volumes of data," continues Bryan. "There are now several specialists that are setting themselves up to provide big data analytics services airlines."

Installing or generating the IoT is an issue of integrating its data feed channels into the internet and on to the data processing platforms. Bryan says this can take as little as two weeks or up to two years, depending on the level of organisation and the number of devices and aircraft that are being connected to the IoT. Enis comments that establishing the IoT is something an airline does incrementally, while the engine manufacturers have been doing this for a long time. "With the right agreement, an airline can get the data into the warehouse and processing platform straightaway," says Enis. "As the number of sensors and amount of data continue to increase, it is the sort of development that is now unlikely to end."

The cost of a total IoT and e-Enablement project is made up of several elements. The main parts are connection to the IoT, the use or acquisition of the data processing platform, and the development of the specialist algorithms that will be hosted on the processing platforms. "Setting up the IoT and connecting devices and fleet assets to the internet is not the most expensive element, since much of the infrastructure already exists," says Bryan. "The aircraft health monitoring (AHM) and engine health monitoring (EHM) data already exist, as does the process to download them from the aircraft to the airline's IT systems and data storage platforms. There are also the same data transmission channels for the several other groups of aircraft health and operational data, which is stored on the aircraft's flight data management (FDM) and flight operations quality assurance (FOQA) unit. There are also companies that are already set up to collect and process particular categories of data. This includes The Weather Company. It collates large quantities of data from a large number of airlines, and processes it before selling it back to the airlines as usable information. This is being repeated across other elements of airline operational activities. There are several new companies setting up to collect specific categories of data from airlines, process it and then sell it in a form that is usable to airlines."

There are several types of data processing platforms. These can be in the Cloud or located in an airline's own data processing centre. "These e-Enablement projects are so large that airlines use them as a means of adopting use of the Cloud within the organisation," says Enis. "The volume and types of data are different to what has been typical at the airline. The cost of investing an in-house data processing centre would be high. It therefore makes sense to use Cloud platform providers, such as Amazon web services and Microsoft Azure. This is especially the case when the e-Enablement and data processing set-up is being grown incrementally. The capacity can easily be stepped up when using Cloud platform providers."

Bryan emphasises that the cost of setting up a Cloud processing facility is relatively small. "Some airlines have still set up their own facilities, and it is in fact the same as the on-going cost of doing business," says Bryan.

On a final note, Bryan advises that airlines have less time to implement e-Enablement and data processing tham some may think. "Ten years is probably all that most have, since the industry is running short of infrastructure capacity. This will force up delays and a variety of associated costs, and e-Enablement and its related advantages will provide a large part of the solution to avoiding these problems." AC