**The 737 MAX is the fourth sub-family in the 737 family. Launched as an alternative to the A320neo family, the 737 MAX has won 5,000 firm orders. The aircraft's design, fuel burn, and technical features are reviewed.**

# Overview of the 737 MAX family

The 737 MAX is the fourth generation of the 737 family, and has won more than 5,000 firm orders since its launch in August 2011. The 737 family has exceeded 13,800 firm orders, making it the second most successful narrowbody programme after the A320. The 737 MAX has been in service for almost two years, and will remain in production for at least another 10 years.

The 737 MAX was launched on the basis that it would provide a 15% reduction in fuel burn and have lower maintenance costs than its predecessor, the 737NG. The 737 MAX also offers other technological features that previous generations of aircraft did not. In addition to operating cost efficiencies, three of the four series of 737 MAX are at least the same size or larger than their 737NG generation equivalents. The four main series are the MAX 7, MAX 8, MAX 9 and MAX 10. These have dual-class seat capacities of 138 to 188 *(see table, page 6)*. What the 737 MAX offers airline operators is examined here.

## Main issues

The 737 MAX's launch came about 20 years after the 737NG, and both families have four main series. A main factor behind the 737 MAX was the launch of the A320 new engine option (neo) generation, which was launched in December 2010. The A320neo family has won about 6,500 firm orders, about 1,500 more than the 737 MAX, over a period of eight months longer than the 737 MAX family. The A320neo family has therefore sold at a faster rate.

The A320neo retains three of the four best selling members of the A320 current engine option (ceo) family: the A319, A320 and A321. Fuselage sizes remain unchanged, but improvements to cabin configuration can realise a small increase in seat numbers.

The A320neo's two main features are a choice of two new generation engines to reduce fuel burn, and an optimised and improved airframe maintenance programme. The two engine choices are the CFM International LEAP-1A engine, and the Pratt & Whitney (PW) 1100G. Both have high bypass ratios, which are the main contributor to the large reduction in fuel burn compared to the respective A320ceo family members.

The 737 MAX was thus launched in response. Boeing maintained its single engine type with the 737 MAX, using the -1B series of the CFM LEAP engine as the sole powerplant. This has a bypass ratio of 9:1. Together with other improvements, the 737 MAX generation members would have about 15% lower fuel burn than their respective 737NG aircraft. Lower fuel burn would also translate into the benefit of longer range.

Other potential areas for cash operating cost reductions are maintenance costs. A new optimised maintenance planning document (MPD) for the 737 MAX is aimed at extending main airframe check intervals, as well as combining tasks and improving physical access to reduce maintenance labour man-hour (MH) requirements.

A second main feature is the increased health monitoring data. This is described in a later section. Like other new generation Boeing types, the 737 MAX has an on-board network server (ONS) in its avionics architecture. An element of this is a wireless data downloading function. This will be used for transferring the large volumes of maintenance-related data the aircraft will generate.

In addition to reduced fuel burn and maintenance cash operating costs, the first three MAX family members have fuselage stretches over their respective 737NG predecessors, which increase seat capacity. While lower fuel burn and maintenance costs will result in lower cost per available seat-mile (ASM) for the MAX aircraft, a further improvement in cost per ASM will be realised by the higher seat counts of the MAX variants. The fourth and largest 737 MAX variant, the MAX 10, has the seat capacity to offer airlines an alternative to the A321.

## Characteristics

The main characteristics of the 737 MAX series are listed *(see table, page 6)*. As described, the 737 MAX has four main members; the MAX 7, MAX 8, MAX 9, and MAX 10. The Boeing standard dual-class cabin configuration gives business class a four-abreast configuration at a seat pitch of 36 inches. The standard economy class in six-abreast has a 32-inch seat pitch. These configurations make it possible to make direct seat number comparisons with the 737NG family, and A320ceo and A320neo families. All three have manufacturer standard dual-class cabin configurations of four-abreast at 36-inch pitch in business class, and six-abreast in economy at 32-inch pitch.

The 5,000 firm orders for the 737 MAX are split between 63 for the MAX 7,


*The 737 MAX family has won more than 5,000 firm orders, about 1,500 fewer than the A320neo family. The MAX 8 has won the lion's share of orders for the family, but there is a lot of interest in the larger MAX 9 and MAX 10 versions.*

3,147 for the MAX 8, 126 for the MAX 9, and 446 for the MAX 10.

In addition, there are orders for about 1,200 aircraft for unspecified series. A minority of these are held by a small number of specified airlines that include AeroLineas Argentinas, Arik Air, Blue Air, Spicejet and United Airlines. There are also several lessors that hold orders for a few hundred aircraft. There are, however, orders for almost 900 aircraft from almost 50 unannounced customers.

## 737 MAX 7

The 737 MAX 7 is 10 feet longer than the 737-700. This gives the MAX 7 a capacity of 138 seats, with two more seat rows and 10 more seats than the 737-700. The MAX 7 has 10 more economy class seats than the -700, the two aircraft having equivalent toilet and galley layouts. The 737-700 is the same size as the 737-300, so the MAX 7 also has a 10-seat advantage over the -300. The MAX 7's 138-seat capacity also brings it closer to the 737-400, which had eight seats more at 146.

A second standard dual-class layout for the 737 MAX 7 gives it a high-density economy-class cabin with a seat pitch of 29 inches. This adds three seat rows and 15 seats to the economy cabin, and takes the total up to 153.

In addition to the 737-700, the A319 is the closest competitor to the 737 MAX 7. The A319ceo and neo have the same fuselage, and the A319 has a standard dual-class layout of 132 seats, six more than the MAX 7. While the A319ceo sold well, the A319neo has only gained 52 firm orders since its first order in January 2012. This is clear evidence that airlines have little appetite for derivative aircraft of this size. The A220-300 (formerly CS300) is slightly larger at 145 seats and has to date won 452 firm orders, about 340 more than the 737 MAX 7 and A319neo combined.

The first 737 MAX 7 was due for delivery in January 2019. It had originally only attracted 63 firm orders, mainly from Southwest and Westjet. This small number of orders makes the MAX 7 the least successful MAX series. Southwest, however, deferred orders for its 737 MAX by up to five years, and Westjet delayed deliveries of its first MAX 7s to 2021. These developments have led to speculation that the MAX 7 may not even be built or delivered.

## 737 MAX 8

The MAX 8 has a dual-class seat capacity of 162 *(see table, page 6)*. The aircraft has a fuselage 41 inches longer than the 737-800. Despite this, the MAX 8 only has two more seats in the same configuration standard. Both aircraft have 12 business-class seats at 36-inch pitch, and 25 rows of economy-class seats at a 32-inch pitch. The 737-800 has a single overwing emergency exit, and has a row of four seats at this position. The 737 MAX 8 has two overwing emergency exits, with two rows of six seats and increased seat pitch. The MAX 8 is therefore still only able to accommodate 25 seat rows of six abreast seats, taking the economy cabin to 150 seats.

An alternative high-density economy cabin with a 29-inch seat pitch and a reduced amount of space for galleys and toilets at the rear increases economy-class seats to 166 seats, with 28 rows of seats. One row at the emergency exit is reduced to four seats.

A comparison of average airline dual-class seat numbers and configurations gives another indication of actual differences in capacity between the two types. The 737-800 is used by more than 50 operators. Most have a two-class cabin, varying in capacity from 138 to as many as 186 seats. The average number of seats is 161.

The 737 MAX has so far been delivered to more than 40 airlines, including: Aerolineas Argentinas, Air Canada, Flydubai, Icelandair, Jet Airways, Oman Air, Turkish Airlines and Westjet. Seat counts vary, with the average at 168. The 737 MAX 8 therefore has a seven-seat higher capacity than the -800, which may be expected given the MAX 8's 43-inch longer fuselage.

The A320 is the MAX 8's closest competitor. The A320ceo is five feet shorter than the 737 MAX 8, and has a standard dual-class cabin of 157 seats, 11 fewer than the MAX 8. Although it is the same length as the A320ceo, the A320neo has a standard two-class capacity of 169, 12 more than the ceo. This is equal to two more economy-class seat rows. The A320neo is able to get more seat rows because of a reconfiguration of its cabin, including moving the location of toilets.

The MAX 8 has attracted more than 3,100 firm orders, making it the most successful model. The largest orders have been placed by AeroMexico (55), Air Canada (50), American (100), China Southern (60), flydubai (200), GOL (120), Lion Air (200), Norwegian group (110), Ryanair (135), Southwest (250), Spicejet (125) and VietJet (100).

In contrast, the A320neo has won 4,179 firm orders. Unlike the 737 MAX family, however, there are only a small number of orders for undecided models. The biggest A320neo orders are for AirAsia (295), easyJet (117), Frontier Airlines (182), GoAir (144), IndiGo (280), LionAir (113) and an unannounced Chinese airline (100). Other fleets of fewer than 100 aircraft are on order for Avianca, Avianca Brazil, British Airways, Lufthansa and Wizz Air.

## 737 MAX 9

The 737 MAX 9's fuselage is 43 inches longer than the 737-900's. The MAX 9 has a standard dual-class layout of 178 seats, one more than the -900's capacity of 177.

**BOEING 737 MAX FAMILY FEATURES & SPECIFICATIONS**

| Aircraft Type | 737 MAX 7 | 737 MAX 8 | 737 MAX 8-200 | 737 MAX 9 | 737 MAX 10 |
|---|---|---|---|---|---|
| Date Certified | Mar '17 | Mar '17 | Mar '17 | Mar '17 | Mar '17 |
| EIS Date | Jan '19 | May '17 | | Mar '18 | 2020 |
| Firm Orders = 4,979 | 63 | 3,147 | | 126 | 446 |
| Standard Dual-Class Seats | | | | | |
| Business Class @ 36-in | 8 | 12 | N/A | 16 | |
| Business Seats Abreast | 4 | 4 | N/A | 4 | 4 |
| Economy Class @ 32-in | 130 | 150 | 200 | 162 | |
| Economy Class Seats Abreast | 6 | 6 | 6 | 6 | 6 |
| Total Seats | 138 | 162 | 178 | 178 | 188 |
| Average Airline Seats | N/A | 168 | N/A | 185 | N/A |
| Fuselage Length - feet | 115.6 | 128.4 | 128.4 | 137.0 | 142.0 |
| **Weight Specs** | | | | | |
| MTOW - lbs | 177,000 | 181,200 | 181,200 | 194,700 | N/A |
| MLW - lbs | 145,600 | 152,800 | 152,800 | 163,900 | |
| MZFW - lbs | 138,700 | 145,400 | 145,400 | 156,500 | |
| Usable fuel - lbs | 45,694 | 45,694 | 45,694 | 45,694 | 45,694 |
| Usable fuel - USG | 6,820 | 6,820 | 6,820 | 6,820 | 6,820 |
| | 6.70 | 6.70 | 6.70 | 6.70 | 0.00 |
| **Engines** | | | | | |
| Engine Type | LEAP-1B27 | LEAP-1B25/27/28 | LEAP-1B25/27/28 | LEAP-1B27/28 | LEAP-1B28 |
| Take-Off Thrust Rating - lbs | 28,040 | 28,040 | 28,040 | 28,040 | 29,320 |
| | | 29,320 | 29,320 | 29,320 | |
| Fan Diameter - inches | 69.4 | 69.4 | 69.4 | 69.4 | 69.4 |
| Bypass Ratio | 9:1 | 9:1 | 9:1 | 9:1 | 9:1 |

The MAX 9, however, has four seat rows and 16 seats in its premium cabin compared to the -900's three rows. The MAX 9 has 27 economy-class rows at a 32-inch pitch, while the -900 has a higher count of 165 due to its smaller premium cabin.

A more equitable seat number comparison is made by comparing the average of airline two-class seat layouts.

This is 185 seats for the 737 MAX 9 versus six fewer seats for the 737-900, equal to an extra seat row for the MAX 9.

The A321ceo has a standard capacity of 184, six seats less than the 737 MAX 9. The MAX 9's average airline configuration of 185 and the A321ceo's average seat capacity of 184 suggests the MAX 9 matches the A321ceo.

The 737 MAX 9 has to date only attracted 126 firm orders. Main customers include Air Canada, AeroMexico, Alaska Airlines, Copa, Turkish Airlines and United.

### 737 MAX 10

The 737 MAX 10 is quoted as having a dual-class seat count of 188, although no details have yet been provided by Boeing. With 16 seats in the premium cabin, it will have 172 seats in the economy cabin.

The A321ceo has a standard and average airline capacity of 184, but the A321neo has eight more seats at 192, even though it has the same fuselage length as the ceo model. Like the A320neo, the A321neo has a higher seat count than the ceo variant because its cabin has been reconfigured. The 737 MAX 10 is therefore smaller than the A321neo by four seats.

The MAX 10 series was launched in 2017, six years after the launch of the original MAX 7, 8 and 9 series. The MAX 10 is a fuselage stretch of the MAX 9. The MAX 10 has a fuselage length of 142 feet, being the longest 737 model and five feet longer than the MAX 9. It is also about three feet shorter than the 707-300/-400. This was the longest and highest capacity version of the four-engined aircraft. Moreover, the 737 MAX 10 is also 12 feet shorter than the 757-200.

The MAX 10 was launched to provide an alternative to the A321, although the A321ceo/neo is four feet longer than the 737 MAX 10.

The MAX 10 has attracted 446 firm orders to date, including a fleet of 100 for United. Other large fleets include flydubai (50), Lion Air (50) and GOL (30). Other airline orders include Virgin Australia, Copa and Westjet. Lessors Aviation Capital, Avolon, CALC, AerCap and GECAS have all placed large orders.

In contrast to the 737 MAX 9 and 10, the A321neo has won 2,287 firm orders. The 737 MAX 9 and 10 may catch up with the A321neo partly from orders for undecided 737 MAX models and from new orders. The large A321neo orders include AirAsia (100), American (100), Delta (100), IndiGo (150), jetBlue (85), (Turkish (92), VietJet (123) and Wizz Air (184).

Interestingly, American, LionAir, Turkish Airlines and VietJet have orders for both 737 MAX and A320neo family models.

## Weight specifications

The main weight specifications of the 737 MAX family members are summarised *(see table, this page)*. The weights included are the maximum take-off weight (MTOW), maximum landing weight (MLW), maximum zero fuel weight (MZFW), operating empty weight (OEW) and maximum structural payload. These are given in imperial pounds (lbs). The aircraft's usable fuel capacity in US Gallons (USG) is also given.

Additional information is given on the aircraft's fuselage length, range with a full passenger payload in nautical miles (nm), and on the aircraft's engine.

Boeing provides a single set of weight specifications for the 737 MAX and NG models, while Airbus offers a large number of weight options for each of the A320 family members.

The 737 MAX was developed to have an engine that provided a double-digit reduction in fuel burn over the 737NG and competing A320ceo predecessors. This mainly required an engine with a higher


*The 737 MAX 8 has a 12-15% lower fuel burn per seat-mile than the CFM56-5B- and V2500-A5-powered A320ceo, and 3.4-4.3% more per seat-mile than the A320neo.*

bypass ratio and therefore fan diameter than previous CFM56-7B, CFM56-3 and JT8D Baby engines. The CFM56-7B powering the 737NG has a 61.0-inch diameter fan. This compares to the 68.3-inch diameter fan for the CFM56-5B powering the A320ceo family. Due to the relatively small intake fan diameters of its engines, the 737 was initially designed with a relatively short landing-gear length, so the wing is lower to the ground than the A320's. The 737's inherent problem has been the installation of a wide-fan engine because of the increased risk of foreign object damage (FOD). The clearance between the ground and the engine nacelles has to be kept at 17 inches.

The A320neo was launched on a similar basis as the 737 MAX, and this was to achieve fuel burn reduction of about 15% compared to the A320ceo. The V2500-A5 and CFM56-5B powering the A320ceo have fan diameters of 63.5 and 68.3 inches, with bypass ratios of 4.9:1 and 5.4-6.0:1.

The A320neo's 15% lower fuel burn has been achieved by using the CFM LEAP and PW PW1100G engines with bypass ratios of 11.0:1 and 12.0:1. This is achieved with fan diameters of 78.0 and 81.0 inches. These larger fan diameters were not a problem for the A320, given its longer landing gear struts.

The 737 MAX's LEAP-1B has a fan diameter that is 11.6 inches less than the PW1100G's on the A320neo at 69.4 inches. The CFM LEAP-1B fan is also 8.6 inches less than the LEAP-1A on the A320neo at 78.0 inches. The -1B's fan diameter was limited by the 737's lower ground clearance and height of the wing, so its bypass ratio is 9.0:1.

The issue of FOD and ground clearance was partly overcome by mounting the engine more forward and higher than on previous 737 generations.

The 737 MAX has also had its landing gear height increased. The nose gear is up to eight inches longer, so an increase in main gear leg length was also required. The LEAP1-B engine is heavier than the CFM56-7B powering the 737NG, and the main landing gear and its supporting structure all have to be larger and stronger. The effect is to increase OEW by about 6,500lbs for a MAX 8 compared to the 737-800. The MAX 8 therefore requires an increase in MTOW of 7,000lbs over the 737-800 to preserve payload and fuel capacity when the aircraft is at or near MTOW for longer missions.

While the high engine bypass ratios account for most of the MAX's improved fuel burn performance, it has several other features that contribute to overall lower fuel burn. The 737 MAX has a split scimitar winglet and a raked wing tip, which account for 1.0-1.5% of the fuel burn reduction over the 737NG. The 737NG has blended winglets as standard.

## Fuel burn performance

The 737 MAX's fuel burn performance has had some initial verification when compared to several competing types. Clearly there are several variables that affect an aircraft's fuel burn, including weather and atmospheric conditions, payload carried, en-route delays and taxi times, and operating factors of speed and altitude. Despite all these variables, an aircraft's fuel burn and operating performance can be compared with other aircraft types on the same basis to show the relative differences between types.

The fuel burn and operating performance of the 737 MAX 8 was compared with several variants of the 737-800, A320ceo, A320neo, and the smaller A220-300 *(see 737 MAX 8 fuel burn & operating performance, Aircraft Commerce, August/September 2018, page 22)*. The comparison was therefore between two new-generation types of almost equal size: the 737 MAX 8 and A320neo. Two older types of the same or similar size were also added to illustrate the relative differences in efficiency between the two generations. A third type, the A220-300, was added to illustrate how this all-new but smaller aircraft compares with the 737 MAX 8 and A320neo.

The performance of these aircraft were compared on five routes of tracked distances from 227nm to 1,821nm. A range of different route lengths is required to illustrate how an aircraft's burn varies with route length. Short routes will result in aircraft not reaching the optimum altitude for the lowest fuel burn in the cruise segment. Aircraft will either fly a ballistic flight profile or operate at a lower and sub-optimum altitude, depending on airspace and air traffic control (ATC) constraints.

As route lengths increase, aircraft can operate at optimum altitudes and cruise speeds, and the cruise portion of the flight increases as tracked distance and route length increase. Fuel burn per mile reduces with increased route length. An aircraft's fuel burn per seat will also reduce with increasing route length, while larger and more modern types have lower burns per seat. An aircraft type's profile of fuel burn per seat-mile versus route length therefore indicates its efficiency relative to other types.

The analysis showed that in the case of all five routes, the PW1127G-powered A320neo was the most fuel-efficient aircraft. It also showed that the LEAP-1A-powered A320neo is closely behind. The 737 MAX 8 burns 3.4-4.3% more per seat-mile than the PW1127G-powered A320neo.

The A220-300 is then only a few per cent less fuel-efficient than the larger 737 MAX 8 and A320neo. The MAX 8 burns up to 4.6% less.

The A320ceo variants with either engine option are consistently better-performing than the 737-800 variants, but both have higher fuel burn per seat-mile than the new generation types.

The 737 MAX 8's fuel burn relative to the 737-800 variants is 13-17% over this range of tracked distances; the actual


*The 737 MAX has entered service with a 36-month base check interval. A base check cycle can be four checks over 12 years, or eight checks over 24 years. Deep access tasks include the removal of the passenger cabin floor and toilets and galleys to gain access for structural inspections. Ageing tasks have yet to be added to the MPD.*

difference depends on the respective 737 MAX 8 and -800 variants.

The 737 MAX 8's fuel burn relative to the A320ceo variants is divided between CFM56-5B4-powered variant, and the V2527-A5-powered aircraft. The CFM-powered aircraft has consistently 7.5-9.0% higher trip burn than the V2527-powered aircraft.

In the case of the CFM56-5B4-powered A320ceo, the 737 MAX 8 therefore has a 15% lower burn per seat-mile than on the shortest route, and this increases to 17-20% on the longer tracked distances of 435-1,821nm.

The MAX 8's fuel burn per seat-mile is 12-13% lower than the more fuel-efficient V2527-powered A320ceo.

The 737 MAX 8's fuel burn improvement over the two main older generation 737-800 and A320ceo models is therefore higher than the general target of a 15% reduction in many cases. It is less than 15% in several cases. The first of these is when the MAX 8 is compared to higher weight and more capable variants of the 737-800; with the difference being lower at 12.5-14.0% in the MAX 8's favour.

Another scenario is the difference between the MAX 8 and V2527-powered A320ceo, which is only 12-13%.

## Maintenance

The 737 MAX family has several design features that have improved its maintenance requirements over the 737NG. The MAX's improvements include a lower number of maintenance tasks, fewer tasks that have deep access and so heavy maintenance requirements, and fewer ageing maintenance tasks.

The 737NG's maintenance planning document (MPD) has about 661 system tasks, 7,651 structures tasks, and 213 zonal tasks. Of the structures tasks, 382 are ageing maintenance tasks which have initial inspection thresholds of 50,000FC and 56,000FC *(see 737NG long-term base maintenance assessment, Aircraft Commerce, October/November 2016, page 46)*. They also have short repeat intervals, and so increase the aircraft's maintenance burden after it reaches the 50,000FC threshold.

The 737NG has a flexible MPD without pre-defined intervals for base checks. Nevertheless, many airlines have base their base check maintenance programmes around a base check interval of 7,500FH and 24MO. There are a large number of tasks that have multiples of these intervals, and so can be grouped into six checks. There are also, however, a large number of out-of-phase tasks with intervals that fall between these multiples. These have to be brought forward and performed early if they are to be included in a base check. The sixth base check has an interval of 12 years and 45,000FH.

The 737 MAX has an MPD with 697 systems and 235 zonal tasks; similar numbers to the 737NG's MPD. The 737 MAX's MPD has 178 tasks, and this does not include ageing tasks. These are bound to be added later, and will be some time after the oldest aircraft in the fleet have been through their first heavy and structural checks. A large number of tasks, similar to 50,000FC and 56,000FC structural tasks in the 737NG's MPD, are likely to be added.

Like the 737NG, the MAX does not have pre-defined base check intervals. A large number of tasks fall due, however, at 15,000FH and 36MO, and so is generally used as the base check interval.

It is not yet clear how many checks there will be in the full base check cycle. Four checks will take the full cycle to 12 years (12YE), and eight checks will take the full cycle to 24YE.

The 737 MAX overall appears to be a maintenance-efficient aircraft. It has entered service with a 36MO base check interval, and so will allow higher rates of utilisation due to reduced downtime for maintenance.

These base check intervals are 12MO and 50% longer than the equivalent checks for the 737NG. This is likely to be related to the system tasks having long intervals because of technology incorporated in their systems and components.

The structural and zonal programmes in the MPD have several tasks that have deep access requirements. These include the removal of passenger cabin floor to gain access for upper and lower lobe inspections at 12YE interval, the fourth base check. There are also the floor panels at the wing centre section at the same interval.

Various flight control surfaces have to be removed at 6YE and 8YE, while there are wet inspections for the passenger compartment floor at 9YE in the galley and lavatory locations. These inspections then have repeat intervals of 6YE, and so every second check will have deep access tasks.

## Data & management

As with all aircraft types, the 737 MAX is supported by a catalogue of technical manuals and documents. These include the aircraft maintenance manual (AMM), structural repair manual (SRM), fault isolation manual (FIM), troubleshooting manual (TSM), illustrated parts catalogue (IPC), aircraft wiring manual (AWM), and several others.

The technical documentation and manuals of Boeing aircraft types have been kept in a variety of standards, which have evolved over the past 10-15 years. Older types that include the 727, 737 earlier generations, 757, 767, 777 and 747 family have changed from printed paper documentation to the electronic format of iSpec 2200, and are written in standard generalised mark-up language (SGML). SGML allows the electronic content to be transferred between personnel and departments, as well as from the


*As with previous 737 family members, the MAX series will have its technical documentation and manuals in iSpec 2200 standard, and written in SGML.*

manufacturer to the airline customer, and from an airline to a maintenance provider.

A new format has been developed for the latest generation aircraft. This is S-1000D, and is the standard for documentation for the 787, A350 and A220 (formerly CSeries). The documentation for these new generation types is written in the format of extensible mark-up language (XML).

While the 737 MAX is a new generation aircraft, its documentation will be provided in iSpec 2200 standard. The only exception is the FIM, which is provided in hyper text mark-up language (HTML) to render the pages viewable on mechanics' mobile devices while working on unscheduled line maintenance tasks.

The documentation for older generation aircraft, and the 737 MAX, is written in SGML, but can be upgraded to XML if the operator requires.

Boeing has for several years offered various on-line services for airlines to manage their documents and technical manuals. The first of these is Maintenance Performance Toolbox. This is an online technical document management system that uses visual navigation methods to manage and locate the documents. The system allows the aircraft operator to troubleshoot aircraft systems when there are technical faults, record structural repairs that are performed on the aircraft, and manage and write or edit maintenance task cards. A fleet's documents can therefore be managed in Maintenance Performance Toolbox, and so do not need to be managed within the operator's own maintenance and engineering (M&E) system.

In relation to Maintenance Performance Toolbox, Boeing offers Technical Authoring Services. This provides another part of the airline's document management services. Boeing staff can create customised technical publications for aircraft configuration changes for airlines.

There is also an Electronic Logbook to replace the traditional paper logbook, and record technical faults and defects as they arise in airline aircraft operation. The Records Module is an electronic repository for digital maintenance records.

The second system is Maintenance Turn Time, one of Boeing's mobile maintenance applications. It allows airlines to quickly identify and resolve non-routine defects while the aircraft is on the line, during a turnaround. The Turn Time system is accessed by line mechanics from mobile devices, making it easier to troubleshoot defects and system malfunctions. This effectively replaces the traditional paper printed TSM or FIM.

## On-board network server (ONS)

Like several other modern Boeing types, the 737 MAX has been equipped with an on-board network server (ONS). This has multiple functions, including: software and data loading; connectivity management; transfer of internet protocol (I.P.) and aircraft communications addressing and reporting system (ACARS); providing network security; hosting the aircraft's quick access recorder (QAR); hosting the on-board maintenance function, which is the modern system for diagnosing maintenance faults and defects; and an electronic engine controller monitoring and reporting function.

There is also the option for the aircraft to have a wireless data transfer system at the airport gate, which can be either WiFi or cellular.

## Data capture

The 737 MAX captures flight operations quality assurance (FOQA) data and maintenance- and systems-related data like other aircraft types. The 737 MAX, however, has introduced 200 status messages and 3,500 maintenance messages from the on-board maintenance function (OMF). There are also 30 maintenance data pages that capture real-time system synoptics from the display system, and also electronic engine controller (EEC) files.

The previous generation 737NG family has flight data acquisition units that capture about 17,600 parameters. This number has been increased to 25,000 for the 737 MAX. All of the parameters on the 737 MAX are also available to the ONS, and its applications. The aircraft condition monitoring system (ACMS) data is also available to the ONS.

The on-board maintenance function (OMF) and network file server (NFS), which is part of the ONS, supports the monitoring of the aircraft while it is in flight, and it can send status messages and maintenance messages in real-time via ACARS to engineering, line maintenance, and maintenance control teams. This data is processed and analysed by the aircraft health monitoring (AHM) system. The ACMS data is also used to analyse technical problems, and in the overall development of prognostics.

The 737 MAX generates a large volume of maintenance-related data compared to the 737NG. In a typical two-hour flight the MAX is estimated to generate about 33 times more data than the 737NG, even though the MAX monitors about 42% more parameters.

The larger volume of data provides the operator with the opportunity to perform big data analytics, using ground-based systems with algorithms to investigate the data, and to provide a predictives service. This is to identify the source of technical malfunctions and system faults in advance of failure, and from this point send the operator recommendations to performance maintenance inspections and tests, or component removals to pre-empt unscheduled maintenance events. Boeing regards the process as making better use of the data. AC