The C Series has been in service for more than 18 months. Charles Williams examines its characteristics, its performance and aspects of its technical operation & management.

Bombardier C Series: initial assessment

The Bombardier C Series has been in service since July 2016. It is in operation with three airlines, although there are outstanding deliveries to another 13 airlines and three lessors. There are two main series of the C Series family: the CS100 and the CS300. To date, there are 24 aircraft in operation, and the C Series is proving to be efficient compared to similar-sized competing types, particularly with respect to fuel burn. The aircraft's technical characteristics and its performance in service are reviewed here.

Characteristics

The CS100 and CS300 are nominally 125- and 145-seat aircraft, although cabin configurations vary between operators. The cabin's width allows a five-abreast seat layout in the economy cabin that is similar to the DC-9 and MD-80 family, although the C Series cabin is wider. Seat and aisle width are therefore superior to the DC-9 and MD-80. The C Series' cabin is not wide enough, however, to allow a six-abreast configuration used by the A320 and 737 families. The C Series seat width in the five-abreast configuration is therefore 18.5-19.0 inches depending on aisle width, compared to a typical seat width of 18 inches for the A320 family and 17.5 inches for the 737NG family that are configured in six abreast. The DC-9/MD-80 standard economy-class seat width was 17.9 inches.

The C Series has several other features that have given it a reputation for superior cabin comfort, including large overhead bins and large passenger windows which give the cabin a light and airy feeling.

CS100 cabin layout

SWISS is the only airline with an active CS100 fleet. It has a seat configuration of 125, due to a combination of four rows of business-class and 21 rows of economy-class seats. The business-class section has seats closed off that are next to occupied seats, and so effectively provides three seats abreast that can be sold. In the configuration that SWISS uses, it has 117 seats that can be sold out of 125.

The CS100's seat capacity puts it close in seat numbers to the A318, MD-87, 737-300/-700 and the 717. The CS100 is slightly larger than the Embraer E-195, which has seat configurations of 112-120 seats. The CS100 is also slightly smaller than the A319, 737-700 and 737 MAX 7, which have average two-class seat counts of 128-130.

This puts the CS100 in a size class of its own, because its 115-125 seat capacity means it is too big to be classed as a regional aircraft.

The CS100 therefore has a large potential market to exploit, by replacing some of these older types, providing an alternative to the 737 MAX 7, and offering the capacity to absorb growth on routes that have been operated with smaller aircraft like the E-190, E-195 and Avro RJ.

There are outstanding orders for the CS100 with Braathens Aviation, Delta Airlines, Gulf Air, the Lufthansa Group, Odyssey Airlines based at London City airport, and PrivatAir. The largest outstanding order for the CS100 is for 75 aircraft for Delta Airlines. The CS100 has won 123 firm orders to date. The type has already outsold the A318.

CS300 cabin layout

SWISS, airBaltic, and Korean Air are the three carriers operating the CS300. SWISS has a 145-seat configuration, with six rows of business-class seats to provide 30 seats in total and 18 saleable seats, plus 23 rows of economy seats to provide a total of 145 seats in two classes, and 133 saleable seats.

airBaltic operates eight CS300s, the first of which went into service at the end of 2016, and has a further 12 aircraft on order. It has configured its aircraft in a single-class, economy cabin layout with 29 rows of five-abreast seats at a 32-inch seat pitch. This provides a total of 145 seats.

Korean Air is the most recent CS300 operator, with the first entering service in December 2017. It has configured its aircraft with five rows of business-class seats with a 36-inch seat pitch, and 20 rows of economy seats at 31/32-inch pitch and a half row of two economy seats at the rear of the cabin. This provides a total of 127 seats.

The CS300's seat capacity makes it larger than the A319 and 737-700, and smaller than the 737-400 and MD-81/2/3/8. There are only a small number of 737-400s in operation with Alaska Airlines. These are configured with 144 seats in two classes. Most 737-400s were configured with about 145 seats in two-class mainline operation.

Delta and American are the last two large MD-80 operators. Their aircraft are configured with 149 and 140 seats in a dual-class configuration.

The CS300's size also puts it at some

The CS100 has seat numbers between about 115 and up to about 125. A main factor in determining seat numbers is the presence and configuration of a business class cabin. The CS100 is pitched between the E-195 and the A319.

point between the A319/737-700/737 MAX 7 and the A3210/737-800/737 MAX 8 - the two groups of aircraft that are being manufactured.

The CS300 is therefore also in a class size of its own. It has a two-class capacity of between 127 and 145 seats, depending on the configuration of a business class cabin. The CS300 has a potentially large market to exploit, since it can offer similar or even lower operating costs than the A319/737-700/737 MAX 7.

The CS300 has gained 249 firm orders to date, from Air Canada, Egyptair, Ilyushin Finance, Lease Corporation, the Lufthansa Group, MacQuarie AirFinance and Republic Airways. Air Canada has the largest order for CS300s at 45 aircraft.

Technical specifications

The CS100 and CS300 have a range of maximum take-off weight (MTOW) options, with the gross weight increasing in 1,000lb increments. In line with this, the CS100 and CS300 both have three different variants of the Pratt & Whitney (PW) PW1500G geared turbofan engine, with three thrust ratings for the CS100 and two for the CS300 *(see table, page 6)*. The turbomachinery of these different ratings is identical, so only a change to the engine's full authority digital engine control (FADEC) unit is required. The PW1500G family has a fan diameter of 73 inches, and an ultra-high bypass ratio of 12:1. The engine is also configured with a two-stage high pressure turbine (HPT). The combination of a bypass ratio of 12:1 and a two-stage HPT gives the engine a low specific fuel consumption (sfc), so the C Series family has low fuel burn when compared to similar-sized alternative types *(see CS300 fuel burn and operating performance, Aircraft Commerce, October/November 2017, page 27)*.

The CS100 has MTOWs of 121,000-134,000lbs *(see table, page xx)*. The MTOW increases in 1,000lb increments, so there are 14 different MTOWs to choose from. The CS100 has a useable fuel volume of 5,790 US Gallons (USG). The increase in MTOW provides the aircraft with additional performance, and increases its range when it is operating at the edge of its payload-range profile.

The aircraft has four maximum landing weight (MLW) options in 1,000lb increments from 112,500lbs to 15,500lbs; three maximum zero fuel weight (MZFW) options of 108,000lbs, 110,000lbs and 111,000lbs; and a typical operating empty weight (OEW) of 77,650lbs. The OEW will vary, however, according to the cabin configuration and galley, and toilet hardware. It excludes in-flight entertainment (IFE) equipment, or extras such as satellite communication (Satcom) hardware.

These MZFW options and OEW will give the aircraft a gross structural payload of 30,350lbs, 32,350lbs and 33,350lbs *(see table, page 6)*. The lowest gross structural payload allows almost no additional capacity for extra freight over a full passenger payload, while the other two specifications allow only a small amount of belly freight.

The four engine variants that are options for the CS100 are: the PW1519G, rated at 18,900lbs of static thrust; the PW1521G, rated at 21,000lbs of static thrust; the PW1524G, rated at 23,300lbs of static thrust; and the PW15125G, rated at 23,300lbs of static thrust. While the PW1525G has the same basic static thrust rating as the PW1524G, the PW1525G has the reserve capacity to provide 5% more dynamic or net thrust. This increase can be used in take-off thrust. The PW1525G can also provide the 5% increase at maximum continuous thrust below 25,000 feet, and so provides more performance for hot and high conditions.

Any of the four engine variants can be operated with any of the MTOW options. The higher-rated engine variants provide the aircraft with improved field and operating performance. The aircraft's configuration provides the CS100 with a range of about 2,760 nautical miles (nm) with a payload of 120 passengers at its highest MTOW option of 134,000lbs.

The CS300 has MTOWs of 132,000-149,000lbs, with increases in 1,000lb increments, so there are 18 different MTOW options for operating the aircraft *(see table, page 6)*. The CS300 and CS100 have the same useable fuel volume of 5,790USG.

The CS300 has six MLW options in 1,000lb increments from 124,500lbs to 129,500lbs; four MZFW options of 118,500lbs, 119,500lbs, 121,500lbs and 123,000lbs; and a baseline OEW of 87,750lbs based on a two-class cabin *(see table, page 6)*. The aircraft therefore has a gross structural payload of 30,750lbs, 31,750lbs, 33,750lbs and 35,250lbs depending on the MZFW option. This payload allows little extra capacity for freight above a full load of passengers with checked luggage (at a weight of 231lbs per passenger). In fact, the two lower MZFW options do not allow a full load of passengers at this average weight.

The CS300 has three variants of the baseline PW1500G: the PW1521G, with a static thrust rating of 21,000lbs; the PW1524G with a static thrust rating of 23,300lbs; and the PW1525G, also with a static thrust rating of 23,300lbs. As with the CS100, the PW1525G can be used to provide 5% more dynamic or net thrust in conditions that require extra performance.

The CS300 has a range of 3,100nm with a passenger payload of 140, and when operating at its highest MTOW option of 149,000lbs *(see table, page 6)*.

BOMBARDIER C SERIES & COMPETING AIRCRAFT TECHNICAL SPECIFICATIONS

Aircraft type	CS100	CS100	CS100	717	737-700	737 MAX 7	A319ceo	A319neo
Engine variant	PW1519G	PW1521G	PW1524G/ PW5125G	BR715 21,000	CFM56-7B24	LEAP-1B26	CFM56-5B7/ V2524-A5	LEAP-1A/ PW1124G
Thrust rating - lbs	18,900	21,000	23,300/	21,000	24,200	to 29,320	27,000	24,000
MTOW lbs	from 121,000 to 134,000			118,000	133,000-154,500	177,000	141,096-166,449	166,449
MLW lbs	115,500	115,500	115,500	102,000	128,000-129,200	145,600	134,482-137,789	140,875
MZFW lbs	108,000	110,000	111,000	96,000	120,500-121,700	138,700	125,663-128,970	132,939
OEW lbs	77,650	77,650	77,650	67,500	86,650	N/A	89,023	89,023
Gross structural payload lbs	30,350	32,350	33,350	28,500	33,850-35,050	N/A	36,640-39,947	43,916
Fuel capacity USG	5,790	5,790	5,790	3,673	6,875	6,820	6,303	6,303
Two-class seats	125	125	125	125	129	129	128	128
OEW/seat - lbs	621	621	621	540	672	N/A	695	695
MTOW/seat - lbs	968	1,040	1,072	944	1,031-1,198	11,372	1,102-1,300	1,300

Aircraft type	CS300	CS300	CS300	MD-83	737-400	737-800	A320ceo	A320neo
Engine variant	PW1519G	PW1521G	PW1524G/ PW5125G	JT8D-219	CFM56-3C1	CFM56-7B26	CFM56-5B4/ V2527-A5	LEAP-1A26/ PW1127G
Thrust rating - lbs	18,900	21,000	23,300/	21,000	23,500	27,300	27,000	27,000
MTOW lbs	from 132,000 to 149,000			160,000	153,000	174,200	169,756	174,165
MLW lbs	129,500	129,500	129,500	139,500	124,000	146,300	145,505	148,592
MZFW lbs	118,500	119,500	121,500-123,000	122,000	117,000	138,300	137,789	141,757
OEW lbs	87,750	87,750	87,750	79,686	74,170	97,663	93,256	95,901
Gross structural payload lbs	30,750	31,750	33,750-35,250	42,314	42,830	40,637	44,533	45,856
Fuel capacity USG	5,790	5,790	5,790	6,981	6,295	6,875	6,506	6,303
Two-class seats	127-145	127-145	145	145	145	158	153	161
OEW/seat - lbs	605	605	605	550	512	618	610	596
MTOW/seat - lbs	910	917	1,021-1,028	1,103	1,055	1,103	1,110	1,082

Structural efficiency

One particular design feature of the C Series is the use of lightweight materials. The fuselage barrel structure has a high portion of Aluminium-Lithium (Al-Li) alloy, the benefits of which are that it is both fatigue- and corrosion-resistant. The aircraft structure therefore has low maintenance requirements, so its structural inspections in its heavy checks, which have an interval of 12 years, will have low non-routine requirements.

The wing box, horizontal stabiliser and vertical stabiliser are built using composite materials, which are lightweight as well as fatigue- and corrosion-resistant. The wings are also manufactured using composite materials, mainly reinforced carbon fibre. Composite materials are also used on the wing-body fairing.

Bombardier has used these fatigue- and corrosion-resistant materials with a high flight cycle (FC) operation in mind. That is, most operators are expected to operate the aircraft at a flight hour (FH) to FC ratio of 1.5-1.7:1. At typical rates of utilisation, the aircraft could generate up to 2,000FC per year. Swiss, for example, is achieving an average utilisation of 2,050FC per year with its CS100 and CS300 fleet.

The use of lighter materials also contributes to the aircraft's low fuel burn performance.

As described, the CS100 is close in size to the 737-700, 737 MAX 7 and A319. These three types have seat configurations of 128-130 seats in a similar cabin layout to SWISS's two-class cabin of 125 seats for the CS100. The 717 has a capacity of 125 seats in a single class arrangement.

The CS100's use of lightweight materials is reflected in its lower OEW per seat when compared with the 737-700, 737 MAX 7 and A319ceo. This gives the CS100 a 50-75lbs per seat advantage over its Boeing and Airbus competitors. This has to be considered in relation to the performance of the types in terms of range capability with this number of passengers. The range capability will be a function of fuel, MTOW and MLW, and therefore fuselage strength. As described, the CS100 has a range of 2,760nm with 120-125

Korean Air is the latest CS300 operator. It has a two-class cabin with a total of 127 seats. This includes five rows of five abreast business class seats at 36-inch pitch, and 102 economy class seats.

passengers, while the high gross weight variants of the 737-700 and A310ceo have a range performance of 2,500nm with 129 passengers, and 2,850nm with 128. The performance of the three main types is close, while the CS100 has an OEW weight per seat advantage.

The CS100 also has an MTOW per seat advantage over the highest gross weight 737-700, 737 MAX 7 and A319ceo variants. The CS100 has an advantage of 126lbs per seat over the 737-700, and 228lbs per seat over the A319ceo/A319neo.

The CS300 similarly has OEW and MTOW per seat advantages compared to types such as the 737-800, A320ceo and A320neo which are configured to have a similar range performance with a full load of passengers to the CS300. These three types have OEW per seat weights that are close to the CS300. This indicates that the CS300 is relatively efficient in terms of weight per seat, given that it has a smaller capacity and its gross weight is 20,000-25,000lbs lower than that of the 737-800 and A320ceo/neo.

Operating performance

The CS300 has proven to be more fuel efficient than the smaller A319ceo and 737-700 types it competes with, as well as the larger A320ceo and 737-800, across mission lengths ranging from 240nm to 2,000nm *(see CS300 fuel burn and operating performance, Aircraft Commerce, October/November 2017, page 27).*

The two smaller types the CS300 principally competes with are the A319 and 737-700. Depending on the A319ceo's engine type, it burns 17-20% more fuel than the smaller CS300 on short routes. The A319ceo burns 11-13% more fuel than the CS300, despite the A319 having 17 fewer seats, on longer routes. On a per available seat-mile (ASM) basis, the smaller A319ceo has a 33-36% higher burn.

The 737-700 has a 10-14% higher burn than the CS300, despite the 737-700 having 16 fewer seats. This translates to the 737-700 having a 24-28% higher burn per ASM.

The A320 and the 737-800 are larger than the CS300. The A320ceo has eight more seats, the A320neo has 16 more, and the 737-800 has 13 more than the CS300.

The A320ceo burns 17-22% more fuel than the CS300, which translates to a 6% higher burn per ASM. The 737-800 burns 28-29% more than the CS300, which is equal to 17-18% more per ASM.

The A320neo shows the improvement that the PW1127G and LEAP-1A26 engines provide over the ceo's CFM56-5B and V2527-A5 engines. The A320neo burns 6-8% more fuel than the CS300. The A320neo's 16-seat advantage over the CS300 translates into the A320neo having a lower fuel burn per ASM than the CS300.

The A320neo has a 10.5-13.5% lower burn than the A320ceo, depending on engine type and route length. If the same fuel burn difference is applied between the A319neo and A319ceo, then the A319neo should have similar or close fuel burn to the CS300 on most mission lengths. This translates to the A319neo having 13% higher burn per ASM than the CS300.

The CS100's gross weight is up to 15,000lbs less than the CS300's. On the same routes with a full payload, the CS100 is likely to have a 15,000-20,000lbs lower all-up weight than the CS300. This will clearly translate to a lower absolute fuel burn, so the CS100 will have a lower fuel burn than the A319neo and 737 MAX 7.

Flightdeck systems

The C Series has incorporated a lot of technology, and has the advantage of being a clean sheet design, rather than a derivative like the 737 or A320 family aircraft. Bombardier has replaced the analogue technology used on the flightdeck in its earlier types with the latest generation technology, including duplex switching, which is an ethernet style of architecture.

The C Series has a suite of avionics based on the Rockwell Collins Pro Line Fusion system. The flightdeck configuration includes the use of: dual global positioning system (GPS) satcom navigation systems; dual flight management system (FMS) computers; and Category IIIa landing capability as standard, with Cat IIIb as an option. For navigation and surveillance purposes, the C Series is also fitted with a traffic collision avoidance system (TCAS), automatic dependent surveillance (ADS) -B out as standard, and ADS-B in as an option. ADS-B out will be used for the aircraft to report its own geographical position, altitude and speed when operating over land. ADS B-in is currently an option on the aircraft, since its use is not yet mandated, although it will be by 2020. It weill be used to receive weather and terrain information that will be displayed on the navigation displays.

The C Series has an aircraft health monitoring system (AHMS) for health monitoring data. The aircraft can simultaneously monitor 5,000 parameters from a possible list of 100,000. The operating airline can choose which parameters are monitored. The aircraft can therefore monitor systems and components which are maintained on an on-condition, and those that are maintained on a condition-monitored basis.

The C Series central maintenance computer (CMC) has a database of 9,000 fault messages for the purpose of system monitoring, and diagnosing or isolating faults in the line maintenance process.

With the use of flightdeck connectivity systems, an operator's engineering department can perform preventative maintenance on systems and components with the AHMS and fault messages that are available. This range of capability is unique to all narrowbodies available on the market. Bombardier states that the A320 family has a similar capability, but to a lesser extent than the C Series.

The C Series has space and wiring for installation of an optional Class 2 Electronic Flight Bag (EFB). An EFB is not a standard fit. The C Series EFB capability is based on the Esterline CMC PilotView Class 2 EFB.

Connectivity and avionic systems have evolved in recent years, especially those that allow large volumes of data to be transmitted to the ground. This includes flight operations quality assurance (FOQA) and flight data monitoring (FDM) data, as well as aircraft health monitoring (AHM) and engine health monitoring (EHM) data.

The C Series has the conventional VHF radio system for flightdeck connectivity, but also has an Iridium Classic satcom system fitted as standard for data transmissions. Both of these can be used for all categories of ACARS transmissions, including safety-related messages.

For on-ground transmissions, Bombardier has fitted the C Series with a Rockwell Collins groundlink unit that provides 3G cellular and WiFi connectivity. This allows airline maintenance personnel to upload data and information, such as FMS database updates, to the aircraft via the groundlink unit or a USB stick.

Technical documentation

The C Series has all its technical documents and manuals provided in an electronic format. None are printed.

The C Series is the third commercial aircraft type, after the 787 and A350, to have its documents and manuals written in S1000D specification and written in extensible mark-up language (XML). This is a format that follows on from ATA iSpec 2200 specification, and written in standard generalised mark-up language (SGML). This is used for the technical documents of many recent types, such as the 777 and A380.

S1000D is used for electronic documentation, and has a modular structure. This differs from the page block structure of previous standards and specifications of iSpec 2200 and its predecessors.

S1000D content is written in data modules (DMs), rather than in page blocks. There are about 15 different categories of DMs, including document headers, pieces of text, pictures and diagrams, arrows, component part numbers (P/Ns), and warning symbols. Several DMs are used to form the contents of what is viewed as a page, on a computer or tablet screen, in hyper text mark-up language (HTML) pages. The DMs are held in a database, and there is a publication module (PM) for each page that defines which DMs to use so that it forms the correct content of a page. A formatting transformation, which is acquired from the aircraft or engine manufacturer, forms the page's content on a screen.

The DM structure has several advantages. The first is that a DM may be used on a large number of different pages in the aircraft's overall documentation. An example is a P/N being used on 25 or 30 different pages of the aircraft maintenance manual (AMM). Under a previous system, such as iSpec 2200, when the P/N had to be changed following a revision or upgrade issued by the original equipment manufacturer (OEM) that publishes the technical documents, all the 25 or 30 affected pages had to be edited individually.

In the S1000D system, the DM which states the P/N is the only item that has to be changed in the database when there is a revision. The publishing module on each of the 25 or 30 pages where the P/N is used will therefore use the updated DM in the future, so each of these pages will show the new P/N.

The implications of this are that document and manual revisions and updates, which are issued by the OEMs three or four times per year, can be authored quickly just by changing the

The CSeries has a generous sized cabin. Aesthetic features include 18.5 inch-wide seats, generous overhead bin volume, large windows and a standard five abreast economy class cabin.

affected DMs. Moreover, rather than the airline or maintenance provider having to update all revised pages, it only has to update the database with a new set of DMs. The revisions and updates to all affected pages, documents and manuals will cascade automatically so that document and manual users have the latest revisions of the documents. It is possible to completely revise a manual, such as the maintenance planning document (MPD) or AMM, overnight.

The use of XML as the language for S1000D content has several advantages. XML has broader capability compared to SGML used in iSpec 2200 content.

First, XML allows the use of more data types and also has mathematical intelligence and functionality. In contrast, SGML only recognises characters. XML therefore allows the use of dates, automated calculations and formulae which may get used in some maintenance tasks that involve calibrations, and the conversion of temperatures between Fahrenheit and Centigrade.

XML also allows relationships between pieces of content and data used. Examples are the interchangeability of different P/Ns for a particular maintenance task or location on the aircraft, or the applicability of a particular maintenance task to a group of aircraft line numbers (L/Ns).

Another feature of content provided in S1000D/XML is that is has an interactive electronic technical publication (IETP) feature. These are electronic hyperlinks between different pages of the same manual, and between different manuals. An example is a link between the P/Ns listed on a page of the AMM and parts listed in the IPC.

The main advantage of this enhanced and intelligent capability is that it allows a fully interactive and paperless maintenance task card, used on a electronic device. It also removes many of the manual steps a mechanic has to perform. An example is physically searching through the pages of an IPC for a part after examining a page in the AMM.

A fully interactive task card will allow mechanics to: record values and measurements in tasks that involve calibrations and will generate responses; locate all relevant AMM task cards and related information on the screen; view a list of all applicable P/Ns for a particular aircraft L/N on a maintenance task card and provide information about their availability in the parts store; send requests for parts and components; record findings; communicate with supervisors and engineering staff; and perform many other functions without using paper or needing to leave the position of work.

A fully electronic, interactive task card and paperless system for maintenance is only possible with the use of content written XML. Some airlines are converting documentation from iSpec 2200 for aircraft types from SGML into XML.

Mathematical functionality and the use of relationships between pieces of data and content in XML are needed for a fully electronic and interactive maintenance process.

IT systems

There are several practical difficulties in making full use of technical manuals and documents in the S1000D standard and written in XML. First, however, it is important to understand how airlines manage most of their documents. The documents include the structural repair manual (SRM), aircraft wiring diagram (AWM), MPD, troubleshooting manual (TSM) or fault isolation manual (FIM), IPC and AMM.

Only the IPC and AMM have to be hosted by the airline's IT systems, because these often have airline edits made to them, and airlines also like to generate task cards for maintenance when planning checks. The IPC has to be edited if the airline wants to add in parts from sources other than the OEM's own parts. The airline will edit the AMM if it wants to change the OEM's standard task cards, or add its own tasks to the approved maintenance programme.

All other manuals are standard, and electronic versions can be hosted by the OEM. They are accessed by the airline through the OEM's documentation portals.

Most airlines host the content of the AMM and IPC, of various aircraft types, on their maintenance and engineering (M&E) IT systems. The difficulty with S1000D/XML content, however, is that the databases of most M&E systems are not structured to make full use of it. A lot of functionality of S1000D/XML content will therefore be lost. An example is that a lot of the S1000D content will have to be updated manually. Moreover, many M&E system databases only understand the characters of SGML language, and so the formulae and ability to perform calculations of the content written in XML is lost.

M&E systems are also configured to host aircraft transactional data, including FH and FC performed, component configuration information, component installation and removal times, component reliability data, performance of maintenance tasks, and MH and materials used to perform maintenance tasks. Many are not designed to host XML-written content. Some M&E systems are adapting new databases to host S1000D specification and XML-written content.

A solution for the IPC and AMM of the C Series is the use of a content management system (CMS), which is interfaced with the operator's M&E system. The CMS will host the XML content of the IPC and AMM, and so allow the airline to make full use of the functionality and capability of the documentation. They could therefore have electronic and fully interactive task cards for maintenance, as an example. The

The CSeries has incorporated a high degree of technology into its design. This includes the provisioning of an eFIM for paperless fault diagnosis, a fly-by-wire flight control system, an Al-Li alloy for the fuselage barrel and composites for the wings and other major structures, and all documentation and manuals provided electronically in S1000D/XML format.

regular revisions and updates for these manuals can also be made quickly and automatically, without manual intervention or the loss of functionality.

A CMS incurs the cost of an additional system, so another option is for the airline to use a third-party CMS vendor to manage the documents as a service.

A third option is for the airline to use the OEM's documentation portal for the IPC and AMM, in conjunction with all other manuals.

Other options are for the XML content to be reformatted into plain text, but some of the functionality of the content will be lost. Pictures and diagrams will also have to be converted. Overall, the DM structure of the S1000D content will be lost, and it will also lose its 'intelligence'.

airBaltic, for example, operates a fleet of eight CS300s, and uses Commsoft's OASES system. "We do not uses the OASES system to manage the C Series documents," says Andris Vaivads, senior vice president of technical operations at airBaltic. "We use Bombardier's web portal service for technical documents and printing maintenance job cards. One issue is that we lease the aircraft, and the lessor wants to have printed maintenance records.

"We are, however, looking at a long-term solution, and it is possible that we could interface the Bombardier portal with OASES," continues Vaivads. "Our long-term goal is to have a fully digital system, and be totally paperless in our technical operations. We have already started this process on the aircraft operations side. We are aiming to host the C Series' technical documents in OASES. This will mean the content losing some of its capability, and we will have difficulties when document revisions and updates are issued."

Despite this, airBaltic does not want to incur the cost of adding a CMS to the OASES system. "We can still get 90% of the benefits of the S1000D standard for the content when using OASES," explains Vaivads. "The other 10% will have to be done manually by our engineering department."

Documentation service

Bombardier provides an on-line service for all documents and manuals for the C Series. These are provided in an electronic format, and written in S1000D standard and XML language, and have the IETP so that users can make cross-references between manuals. The flight operations manuals can also be provided to airlines on paper for use by flight crews, line mechanics, and staff in maintenance control and flight operations departments.

Bombardier has several services for airlines to view these manuals. One is through an IETP, which is a digital viewer application that allows users to navigate between pages and manuals on screen. The IETP is only available through the iflybombardier.com portal.

The IETP is also available as a standalone application on a user's computer, and the updates and revisions are sent to the user's system whenever they are published.

The IETP is also available as a standalone intranet application at an operator's facility, again with updated and revisions sent to the user at time of publication. It is also compatible with mobile devices and tablets.

The S1000D/XML data and content can also be loaded onto an operator's IT system and viewer application. Some of the manuals can also be viewed through an electronic flight bag (EFB) on the aircraft's flightdeck. An option is for the manuals to also be loaded onto a tablet, with regular updates to content being made when the devices are on-line. This system will allow line mechanics and the staff in various ground departments to diagnose faults, prepare rectifications, request relevant components, and perform line maintenance without the use of electronic manuals.

Another element of engineering management and line maintenance is AHM. Bombardier provides three services related to its AHMS. The first of these is the real-time monitoring (RTM) that allows users to track faults and information messages on the ground in real time as they occur on the aircraft. Other data from the rest of the fleet is also used to provide additional information. The AHM data transmitted is linked to the troubleshooting manual, which is an electronic fault isolation manual (eFIM).

While the eFIM is provided to operators as part of the Bombardier suite of documents, it is actually a product called Spotlight that has been developed by Casebank Technologies of Toronto, Canada. "The eFIM is an off-line or on-board application, and we developed the software for the system," says Phil D'eon, chief executive officer at Casebank Technologies. "The eFIM does not work like a traditional printed FIM. Bombardier has a suite of services called Flightlink, which performs analytics on the aircraft's component and system fault messages that are generated by the aircraft's on-board maintenance computer (OMC). Flightlink feeds the fault codes into the eFIM. The eFIM we have developed is a reasoning engine that looks at a diagnostic database.

"The eFIM is very automated, so it removes many of the manual steps a mechanic has to perform with a traditional printed FIM," continues D'eon. "A traditional FIM or TSM is created by engineers when the aircraft is being designed. It attempts to list all the possible causes of a component or system fault. These are all built into a fault tree, which is then used by mechanics to diagnose a fault.

The problem is, however, that new causes of a technical difficulty may be found when the aircraft is in operation, so the fault decision tree has to be re-designed."

The eFIM has been configured so that the fault decision tree does not have to be re-designed every time a new cause for a fault is discovered in operation. Instead, the reasoning engine adds the new cause into the fault tree. "The reasoning engine allows the mechanic to find a solution faster than a traditional TSM or FIM.

The eFIM system is used by an operator's line mechanics and maintenance control department. It is available on tablets and PEDs. It periodically requires connectivity to update the system, and when in WiFi range will alert the user that an update is due.

A second service is data management. This allows operators to define reports and parameters that they would like to see automatically downloaded from the aircraft into a secure repository.

A third product is data analytics. Bombardier is developing this service to analyse trends and define algorithms to analyse aircraft systems and component health, and to set alerts when thresholds are approached or reached.

The issue of generating task cards for line and base maintenance is the most complex for the C Series. This is because of the S1000D/XML content, and the issues with the capabilities of most airlines' M&E systems. To circumvent this issue, Bombardier provides a Job Card Generator, which allows airlines to author job cards for maintenance via a portal.

Maintenance programme

The C Series' maintenance programme has been developed using maintenance steering group (MSG) 3 principles, as is expected for an aircraft of this generation.

The C Series' maintenance programme is based around an A check interval of 850FH and a base check or 'C' check interval of 8,500FH. At typical rates of utilisation this can be about three years for most operators. These intervals are longer than for the equivalent checks on the 737 and A320 families.

In addition, there are two larger base checks in the C Series' maintenance programme. There is a minor structural check with a calendar interval of six years (YE), which presumably would be combined with every second C check by most operators. There is also a heavy structural check with an interval of 12YE. This is likely to be combined with every second minor structural check and every fourth C check.

Both the minor and major structural checks and 6YE and 12YE involve the removal of interior items. The 6YE check does not, however, involve the entire removal of the aircraft's interior. The use of Al-Li alloy on the fuselage barrel, and composites in many places on the wings and tail structures makes the aircraft less prone to corrosion and fatigue. This should contribute to fewer structural repairs and non-routine rectifications in the base checks performed during its operational life.

In addition to the use of the Al-Li alloy and composites in the main sections of the aircraft's structure, Bombardier has designed the C Series with strategically positioned access panels located around the aircraft. These are to improve accessibility for maintenance. Direct maintenance cost in terms of labour and parts inputs, reliability and ease of maintenance were all key design considerations. As an example, additional stress and robustness testing were performed on all components to ensure high reliability. Validation of routine and non-routine maintenance tasks were performed on the aircraft to confirm the documented maintenance task procedures, and to optimise task time. AC