The number of active and stored narrowbodies totals more than 17,000. The fleet consists of a mix of legacy aircraft, modified variants of legacy aircraft, new types and large regional jets entering the narrowbody market. Fleet sizes, distribution, age and forecasted maintenance requirements are examined here.

Size of the narrowbody airframe base check market

The global narrowbody fleet of just over 17,000 units makes up 55% of the commercial aircraft fleet. While the definition of a narrowbody varies, for the purpose of this article the fleet includes the in-service and stored 737 Classic (737-300/-400/-500), the 737 Next Generation (737-600/-700/-800/-900), the 757-200/-300, the A320 current engine option (ceo) family (A318/A319/A320/A321), and the MD-80/-88/-90.

Also included in the article are the new emerging fleets of the 737MAX and the A320 new engine option (neo) family, and the survivors of the legacy fleet the 727-100/-200.

The Airbus A220 (formally Bombardier CSeries) and Embraer E2 family are noted in the article separately. The new-to-service aircraft types are blurring lines between the large regional and narrowbody markets, but in general they will be targeted by a different group of maintenance repair and overhaul (MRO) organisations.

Data for most of the aircraft in service (including build details, operational statistics and ownership) are available throughout the industry in different formats for analysis. Such data supplied to *Aircraft Commerce* for this article provides a snapshot of the characteristics of the narrowbody fleet from mid-October 2018 *(see table, page 31)*.

This data is fluid in nature. New aircraft are entering service daily, others are being retired, and operators are moving portions of their fleets in and out of storage. Fleet details that include quantity, status, purpose, age, and utilisation can be used to gain insight into, not only fleet size, but also the fleet's base maintenance check requirements.

As an example, narrowbody quantities, region of use, utilisation characterises, maintenance programme type, and predicted maintenance events are examined here.

For details on the narrowbody fleet engine MRO market see *'Narrowbody engine MRO market analysis, Aircraft Commerce, February/March 2017, page 47.'*

The narrowbody fleet

The narrowbody fleet operates a mix of domestic and international operations, depending on where the fleet is based.

The regions with the three largest narrowbody fleets are the Asia Pacific (5,752 aircraft), Europe (4,561) and North America (4,465). The smaller fleets are South America (1,167), the Middle East (695) and Africa (545) *(see table, page 32)*.

There is a small number of narrowbody aircraft (15) with no assigned operator country, and an 'undisclosed' operator. 13 of these aircraft are stored.

The A320ceo family makes up the larger fleet numbers in Europe, the Middle East and South America. The 737 Next Generation (NG) makes up the larger fleet types of North America and Africa. In the Asia Pacific the numbers of A320ceo and 737NG aircraft are similar.

The three largest regions in terms of fleet orders are the Asia Pacific (3,218), Europe (2,373) and North America (2,123). There are a large number of orders (1,328) currently unassigned to a country *(see table page 32)*.

The 'on order' figures noted are always considered only as guides. Airlines are sometimes able to negotiate some flexibility (or even the option to cancel) when they place orders.

As a side note, a small number of aircraft change operational regions on leases for seasonal flying requirements. These aircraft are listed in the tables under primary operator country and, therefore, primary region of use.

An overview of fleets per region follows.

North America

The North American fleet is made up of 4,261 in-service and 204 stored aircraft over 137 listed operators in the United States (US) and Canada.

The US narrowbody in-service fleet is 3,955 aircraft. The larger operator fleet sizes include American Airlines (776 aircraft), Southwest Airlines (741), Delta Air Lines (643), United Airlines (579) and Alaska Airlines (231).

The Canadian narrowbody in-service fleet consists of 306 aircraft. Larger operators include WestJet (118) and Air Canada (88).

Of the North American fleet, 244 aircraft are freighters. The larger fleets are FedEx (111) and UPS Airlines (75).

The business and VIP-configured narrowbody fleet is comprised of 63 aircraft. Other varying primary role functions apart from passenger service include: 11 Combi (passenger and freight): 17 Quick Change (QC) aircraft (full passenger conversion to full freighter); six waterbombers, 10 aircraft listed as experimental; and 83 with military roles.

The region has 2,123 aircraft on order for 22 different operators and aircraft lessors. These aircraft are due to be delivered over the next 10 years: 2,009 orders in the US and 114 in Canada. The larger orders in terms of US airlines include American Airlines (185), Delta Air Lines (190) and Southwest Airlines (271). In Canada this includes Air Canada (43), and WestJet (47).

Lessors with large aircraft orders in place include GECAS (308), Air Lease Corporation (194) and Aviation Capital

GLOBAL NARROWBODY FLEET - IN-SERVICE & STORED AIRCRAFT

Aircraft type	In service & stored fleet	In service passenger	In service freighter	In service VIP or special	Stored aircraft	Youngest aircraft	Oldest aircraft	Average fleet age	Highest listed FH	Highest listed FC	Aircraft on order
MD-80/-88	425	259	13	14	139	19	37	26.9	91,804	62,869	
MD-90	50	50				19	23	21.4	61,919	40,175	
727-100	10		4	6	No data	47	53	50.8	70,395	59,289	
727-200	57	3	44	10	No data	34	48	38.2	71,662	51,695	
737-300	457	181	117	41	118	19	33	24.9	81,490	65,279	
737-400	358	140	137	17	64	18	30	24.8	76,934	56,180	
737-500	205	156		12	37	19	28	23.8	73,571	59,771	
737-600	39	39				12	20	15.8	46,447	39,811	
737-700	1,206	1,020	4	146	36	1	21	13.5	71,926	51,297	3
737-800	4,999	4,804	4	128	63	1	21	7.4	71,651	42,408	142
737-900	530	518		7	5	1	18	5.8	61,111	27,818	34
757-200	715	308	301	33	73	14	36	23.6	109,827	46,134	
757-300	55					14	20	16.6	62,960	21,249	
A318	64	41		19	4	5	16	11.3	33,168	27,308	
A319ceo	1,404	1,289		72	43	1	23	12.9	70,035	46,355	20
A320ceo	4,269	4,166		27	76	1	29	9.2	88,756	53,997	109
A321ceo	1,652	1,631		3	18	1	25	6.9	66,365	51,927	110
A319neo	1			1			1	1	No data	No data	55
A320neo	392	387	1		4	1	4	0.9	7,867	5,141	3,733
A321neo	88	80	2		6	1	2	0.7	5,000	1,533	1,903
737 max - TBD*									N/A	N/A	1,468
737 MAX 7	1			1			1	1	No data	No data	65
737 MAX 8	211	209		1	1	1	2	0.54	5,190	1,972	2,429
737 MAX 9	12	10		2		1	1	0.46	1,017	364	135
737 MAX 10									N/A	N/A	446
Totals Oct 2018	**17,200**										**10,652**

Information from fleet survey October 2018 in service & stored aircraft only. The 727-100/-200 figures are for active aircraft only.
*TBD = variant on order to be determined

Group (127).

North America has the highest number of aircraft listed as stored, with 204 aircraft across 58 operators/leasing companies. The operator with the largest number of stored aircraft is American Airlines with a mix of MD-80s (26) and 757-200s (3).

For aircraft fleet types and aircraft on order for the North American region, *see tables, page 32.*

Europe

The European fleet includes 4,392 in-service and 169 stored aircraft over 242 operators and 44 countries. Europe has the highest number of listed operator countries.

Countries with a high number of in-service aircraft include Ireland (575 aircraft), United Kingdom (569), Russia (518), Germany (436) and France (186).

The largest operators include Ryanair (449), Turkish Airlines (179), Lufthansa (177), Aeroflot Russian Airlines (162), easyJet (181), British Airways (134), easyJet Europe (113) and Vueling (113).

Of the European fleet, 135 aircraft are freighters. Large fleets are with DHL Air (25), West Atlantic (21), ASL Airlines (Belgium, France, Hungary and Ireland) (40) and European Air Transport (15).

The regional business and VIP fleet is made up of 81 aircraft. Other varying primary role functions include one Combi, 11 QCs, three waterbombers, five experimental aircraft, and six aircraft with military roles.

On order in the region are 2,373 aircraft for 163 different operators. Larger orders include Wizz Air (264), Avolon (233), Turkish Airlines (163), Norwegian (186), Ryanair (141), Lufthansa (103) and easyJet (114).

Leasing companies listed as having large orders include AerCap (192), and SMBC Aviation Capital (176).

For aircraft fleet types and aircraft on order for the European region, *see tables, page 32.*

Asia Pacific

The Asia Pacific fleet is made up of 5,626 in-service and 126 stored aircraft, with 263 operators and representing 39 countries.

Countries with a high number of in-service aircraft include China (2,913 aircraft) India (496), Indonesia (391), Japan (273) and Australia (263).

The largest operators include China Southern Airlines (464), China Eastern Airlines (329), Air China (286), Shenzhen Airlines (181), IndiGo (178), Hainan Airlines (166), Xiamen Airlines (158) and Lion Air (110).

Of the Asian Pacific fleet, 157 aircraft are freighters. SF Airlines has the largest narrowbody freighter fleet with 43 aircraft, while China Postal Airlines has 27. Both fleets comprise a mix of 737-300, 737-400, and 757-200 aircraft.

The region's business and VIP fleet comprises 79 aircraft. Other varying primary role functions include two Combi, three QC, and 28 aircraft with military roles.

On order in the region are 3,218 aircraft for 79 different operators. The larger orders include IndiGo (378), AirAsia (377) and GoAir (122).

Lessors with large outstanding orders include China Aircraft Leasing Company (181) and CBD Aviation Lease Finance (157).

For aircraft fleet types and aircraft on order for the Asia Pacific region, *see tables, page 32.*

South America

The South American fleet includes 1,106 in-service and 61 stored aircraft over 98 operators and 23 countries.

Countries with the largest in-service fleets include Mexico (246), Brazil (319), Chile (89), Panama (85) and Argentina (73).

The largest operators include GOL (116), LATAM Airlines Brazil (109),

CURRENT IN SERVICE & STORED GLOBAL NARROWBODY AIRLINER FLEET PER OPERATOR REGION

Region	MD-80/-90	727-100/ -200	737-300/ -400/-500	737/-600/-700 -800/-900	757-200/ -300	A320ceo family	A320neo family	737 MAX 7/8/9	Total by region
Africa	17	15	132	242	5	130		4	545
Asia Pacific	20	6	249	2,445	92	2,611	247	82	5,752
Europe	31	3	353	1,543	152	2,332	112	35	4,561
Middle East	50	2	42	172	7	407	2	13	695
North America	297	18	129	2,037	507	1,351	49	77	4,465
South America	58	22	107	333	7	557	71	12	1,167
Unassigned	2	1	8	2		1		1	15
Total by aircraft type	**475**	**67**	**1,020**	**6,774**	**770**	**7,389**	**481**	**224**	**17,200**

CURRENT ON ORDER GLOBAL NARROWBODY AIRLINER FLEET PER OPERATOR REGION

Region	MD-80/-90	727-100/ -200	737-300/ -400/-500	737-700 -800/-900	757-200/ -300	A320ceo family	A320neo family	737 MAX 7/8/9/10	Total by region
Africa				2			26	53	81
Asia Pacific				27		36	2,082	1,073	3,218
Europe				30		38	1,418	887	2,373
Middle East						15	324	300	639
North America				69		83	893	1,078	2,123
South America						21	601	268	890
Unassigned				51		46	347	884	1,328
Total by aircraft type				**179**		**239**	**5,691**	**4,543**	**10,652**

Copa Airlines (79), Volaris (70), LATAM Airlines Chile (65), Avianca (62), Interjet (63) and Aeromexico (53).

Of the South American fleet, 54 aircraft are freighters. Operator Sideral Air Cargo has the largest freighter fleet with two 727-200s, three 737-300s, and six 737-400s. The next highest is Aeronaves TSM with nine MD-80s.

The South American business and VIP fleet comprises 20 aircraft. Other primary narrowbody role functions include one Combi, four QC, and four military multi-role aircraft.

There are 890 aircraft on order for 18 different operators in the region. The larger orders include GOL (137), Avianca (127) and Volaris (117).

For aircraft fleet types and aircraft on order for the South American region, *see tables, this page.*

Africa

The African fleet includes 475 in-service and 70 stored aircraft over 111 operators and 41 countries.

Countries with large fleets of in-service aircraft include South Africa (88), Egypt (68), Nigeria (41), Morocco (47) and Tunisia (39).

The largest operators include Royal Air Maroc (39), Egypt Air (37), Air Algerie (32), Tunisair (26), South African Airways (23) and Ethiopian Airlines (22).

The African fleet includes 32 freighters. The operator Serve Air has the largest narrowbody freighter fleet, comprising five 727-200s and two 737-300s.

In addition, the region has 18 business and VIP aircraft. Other primary role options include one Combi and three QC aircraft.

Firm orders from the African region include 81 aircraft for nine different operators. The larger orders include Ethiopian (27) and Egyptair (15).

For aircraft fleet types and aircraft on order for the African region, *see tables, this page.*

Middle East

The Middle East fleet includes 651 in-service and 44 stored narrowbodies over 103 operators and 13 countries.

Countries with the largest in-service fleets include the United Arab Emirates (159), Saudi Arabia (145) and Iran (103).

The largest operators include Saudia (68), flydubai (58), Qatar Airways (42), Air Arabia (40), Etihad Airways (32) and Oman Air (31).

Only two aircraft in the Middle East fleet are freighters, which are listed with Texel Air in Bahrain.

The Middle East has 79 business and VIP aircraft. Other primary role functions include one medevac 757-200.

There are 639 aircraft for 15 different operators on firm order in the region. The larger orders include flydubai (244), ALAFCO Aviation Lease and Finance Company (98) and Flynas (80).

For aircraft fleet types and aircraft on order for the Middle East, *see tables, this page.*

Base maintenance

For most of the narrowbody fleet, the original equipment manufacturer (OEM) maintenance planning documents (MPD) are either based on the MSG-2 (Maintenance Steering Group) or the latter MSG-3 maintenance principles.

The MSG-2 guided MPDs were introduced in the 1970s to establish the new concept of condition monitoring to the existing 'hard-time' and 'on-condition' inspection requirements of the maintenance programmes.

As a general overview, the MSG-2 MPDs contain inspection requirements that could be grouped into a series of numbered 'C' checks to be annotated when the task was due in a cycle of checks, such as C1, C2, C3 and C4.

Within MSG-2 maintenance programmes, it is common to see corrosion prevention and control programme (CPCP) calendar-driven tasks controlled on separate thresholds and repeat intervals to those of the C check or FH-driven structural inspection tasks.

MSG-3 maintenance programmes were introduced in the 1980s. These MPDs included inspection intervals that were FH-, FC- and/or calendar-driven, and assessed the aircraft at the system level rather than the component level.

The MSG-3 MPDs do not have one single 'A' or 'C' threshold parameter, but incorporate FH, FC or calendar backstops to each task. These backstops are used to cover the varied aircraft utilisations. Operator utilisation,

GLOBAL NARROWBODY FLEET ESTIMATED C & HEAVY MAINTENANCE VISITS PER AIRCRAFT TYPE

Aircraft type	2017 in service fleet	2017 C checks	2017 HMV	2018 in service fleet	2018 C checks	2018 HMV
727-100/-200	100	34	8	74	22	7
737-300/-400/-500	794	477	66	750	381	66
737-600/-700/-800/-900	6,320	3,014	1,678	6,621	3,166	1,819
737 MAX family	70			350	70	
757-200/-300	684	453	118	647	439	102
A318/19/20/21ceo	7,007	3,126	1,327	7,107	3,148	1,425
A319/20/21neo	256	70		727	186	
MD-80	329	223	53	262	170	46
MD-90	62	27	10	55	32	5
Totals	**15,622**	**7,423**	**3,260**	**16,592**	**7,614**	**3,470**

Source: ICF Consulting

therefore, became the main driver for the pattern and structure of base maintenance inputs. The term 'C' check, however, is still used to refer to the grouping of these check requirements.

The CPCP programme of inspections was absorbed/aligned with other zonal and structural inspection tasks in MSG-3 MPDs for greater maintenance efficiencies.

For aircraft that entered service during or before development of MSG-3, the option to bridge from an MSG-2 to an MSG-3 maintenance programme did exist. It was left to operators to make the economic decision themselves.

In the case of the 757, the MPD was progressed to MSG-3 as standard for all operators.

There are options for operators to carry out maintenance requirements over a 'phased' period instead of C checks. This breaks maintenance requirements into numerous overnight or small downtime packages until structural checks are due. These phased maintenance work packages will vary by operator.

An overview of the 'blocked' C check requirements of each narrowbody type follows.

737 Classic

The 737 Classic (-300/-400-/-500) entered service in 1984, and ceased production in 2000. Before this, the 737-100/-200 models were in operation from 1968.

Of the remaining 737-300/-400/-500s in service, just over half are passenger aircraft, while the rest are freighters, VIP-configured, or adapted for special purpose roles.

The 737 Classic uses the MSG-2 maintenance planning principle, although over the life of the aircraft an MSG-3 maintenance programme was made available for operators.

The 737 Classic MSG-2 maintenance programme is based on utilisation of 1.4FH per FC, and 8.0FH per day. This equates to just over 2,900FH per year.

The recommended 'A' check interval is 250FH. There are four A check groups of tasks specified for 737 maintenance, which are called A, 2A, 4A and 8A tasks. These can be arranged into a cycle of block checks or equalised checks.

The recommended C check interval is 4,000FH. C check task groups are specified as 1C, 2C, 4C, 6C and 8C. These can also be arranged into a cycle of eight block checks: C1 to C8 checks.

The 'D' check interval is equivalent to a 6C or a Structural Inspection (SI) at 24,000FH, coinciding with the C6 check.

There are also special cyclic or monthly inspections for the nacelles and pylons, including engine-off inspections every 45 months.

A wide range of annual utilisations is observed for the classic fleet. The highest annual FH utilisation aircraft is a 737-500 with 4,345FH and 2,347FC. This equates to an average ratio of 1.9FH per FC. The highest annual FC utilisation aircraft is a 737-400 with 3,541FC and 2,420FH. This equates to an average ratio of 0.7FH per FC.

For the more active passenger and freighter aircraft an average annual utilisation could be taken as 2,250FH and 1,600FC. This works out at a rate of 1.4FH per FC. Considering the C check FH guide is 4,000FH, a C check would be required every 20-22 months.

The CPCP programme for this type runs on a calendar basis with varying initial and repeat intervals. This results in multiple requirements for large access requirements out of sync with the FH-driven C check and SI tasks. It is possible, therefore, that a C1 check could require entire cabin floor removals for calendar driven CPCP tasks.

The 737 Classic MSG-3 maintenance programme is based on a check cycle around the large grouping of tasks at 4,000FC or 4,000FH/18MO. The maintenance tasks are FH-, FC- and/or calendar-driven with CPCP tasks no longer on separate intervals to the main SI tasks.

The 737 Classic represents the largest number of stored aircraft in the narrowbody fleet, along with the MD-80/88.

737NG

The 737NGs entered service in 1997. The 737NG fleet is the second-largest narrowbody fleet behind the A320ceo family.

The 737NG maintenance programme has task intervals expressed in FH, FC and calendar time, or a combination of these.

The 737NG MSG-3 maintenance programme blocked or phased programme was developed with the assumption of an average utilisation of 1.8FH per FC and 9FH per day across the fleet variants.

The recommended 'A' check packages of tasks are to be carried out every 90 days. A check groupings and work packages will be determined by each operator to match utilisation of the aircraft.

The guide 'C' check interval is 7,500FH. This aligns with the large grouping of tasks at the same interval.

Heavy structural inspections are primarily calendar-based, with thresholds at 6YE, 8YE, 10YE and 12YE. Repeat intervals are often reduced.

Most of the NG fleet are passenger-configured aircraft with a wide range of utilisations for check planners to monitor.

The highest annual FH utilisation aircraft is a 737-700 with 5,380FH with 1,847FC. This equates to 2.9FH per FC on average.

The highest annual FC utilisation aircraft is a 737-700 with 3,315FC and 3,529FH. This equates to 1.1FH per FC on average.

An average annual utilisation of mainline and low-cost passenger fleets could be taken as 3,200FH and 1,600FC. This works out at a FH to FC ratio of 2:1, and would equate to a C check being required every 24MO.

Maintenance for the 737 Boeing Business Jet (BBJ) is carried out via a separate low utilisation MPD. Tasks are FH-, FC- and calendar-driven with a guide C check interval of 36MO. There are 129 BBJs in service.

737 MAX

The MAX 8 entered service in May 2017. The MAX 9 entered service March 2018.

The 737 MAX maintenance

programme MSG-3 based MPD uses FH, FC and calendar inspection parameters. It was developed with the assumption of an average utilisation of 9.0FH per day and 1.9FH per FC.

The recommended 'A' check packages are to be carried out at 120 days, with a base maintenance 'C' check at 15,000FH/36MO.

As per many maintenance programmes, some inspection task thresholds and intervals can be de-escalated for packaging into C checks and HMV as applicable for each operator's convenience. Savings can be made if access is already gained to inspection areas needed.

For heavy checks, there are large structural task groups with thresholds of 6YE, 6YE and 18,000FC, 9YE and 18,000FC, 10YE and 30,000FC, and 12YE and 36,000FC (with a repeat at 8YE and 24,000FC).

As the 737 MAX is new to service, a full year's utilisation data is limited.

The highest FH annual utilisation aircraft is a MAX 8, with 4,527FH and 1,541FC, operated by Lion Air. This equates to 2.9FH per FC on average.

The highest FC annual utilisation aircraft to date is also a MAX 8, which has accumulated 1,699FC and 4,208FH. This equates to 2.5FH per FC on average.

The annual fleet utilisation information available for the aircraft that entered service in 2016 and 2017 is 2,756FH and 1,118FC. This equates to a FH:FC ratio of 2.4:1. Based on these utilisations, the aircraft will reach the calendar threshold before the FH threshold for their first base checks.

757

The 757 aircraft entered service in 1983 and production was stopped in 2004.

The aircraft type was initially maintained under the familiar MSG-2 letter checks and has seen many revisions over the years. In May 2010 its MPD was updated to the guidelines of MSG-3 fully using FH, FC and calendar parameters.

The recommended 'A' check packages of tasks are to be carried out every 750FH. Based on utilisation of 8.0FH per day, the check will fall due every three months.

The guide 'C' check interval is a frequency of 6,000FH/18MO, while the basic structural or 'SC' check parameters are in frequencies of 3,000FC/18MO.

One exception to the standard MPD guide check intervals is the Boeing Low Utilisation Maintenance Programme (LUMP) for operators that accumulate less than 100FH per month per aircraft, or 1,200FH per year. The Boeing LUMP MPD is still using calendar tasks, 1C to 4C, while still on a 3YE C check interval.

Of the 757-200/-300s built, just over half remain as passenger aircraft. The rest of the fleet are freighters, VIP-configured, or adapted for a special purpose role.

The 757's fleet annual utilisation rates vary greatly. The highest annual FH utilisation aircraft is a 757-200 with 4,493FH and 857 FC. This equates to 5.2FH per FC on average.

The highest annual FC utilisation aircraft is also a 757-200 with 2,032FC and 2,594FH. This equates to 1.3FH per FC on average.

An average annual utilisation of the passenger fleet is 3,060FH and 876FC, with an FH to FC ratio of 3.5:1.

An average annual utilisation of the freighter is 1,900FH and 853FC. This works out at an FH:FC ratio of 2.2:1.

Both sets of average utilisation figures put the fleet within the normal parameters for base checks, which are triggered by 18MO calendar backstops rather than FH.

GLOBAL ACTIVE NARROWBODY FLEET ESTIMATED C CHECK & HEAVY MAINTENANCE VISITS PER REGION

World region	Aircraft group	2019 Fleet	2019 C chks	2019 HMVs	2020 Fleet	2020 C chks	2020 HMVs	2021 Fleet	2021 C chks	2021 HMVs
Africa	727-100/-200	10	3	2	7	4	1	5	0	0
	737 Classic	82	40	8	74	44	7	66	40	5
	737NG	255	113	75	263	122	82	270	115	89
	737 MAX	6	2		23	6		51	22	
	757-200/-300	5	3	1	5	4	1	6	5	1
	A320ceo	150	58	35	159	77	35	168	65	38
	A320neo	17	14		35	3		43	32	
	MD-80/-90	7	5	1	6	5	1	5	3	0
Africa Total		**532**	**239**	**122**	**573**	**266**	**126**	**613**	**282**	**133**
Asia Pacific	727-100/-200	3	1	0	2	1	0	2	1	0
	737 Classic	267	137	21	240	152	18	213	100	15
	737NG	1,548	729	431	1,545	727	464	1,530	642	497
	737 MAX	187	52	0	338	187	0	473	330	3
	757-200/-300	140	100	18	130	88	23	120	77	27
	A320ceo	2,540	1,083	528	2,508	1,127	581	2,460	1,048	601
	A320neo	446	185	0	651	260	9	885	381	42
	MD-80/-90	9	7	1	7	6	1	6	1	1
Asia Pacific Total		**6,019**	**2,726**	**1,281**	**6,463**	**2,917**	**1,432**	**6,892**	**3,168**	**1,545**
Europe	727-100/200	3	1	0	2	1	0	2	1	0
	737 Classic	267	137	21	240	152	18	213	100	15
	737NG	1,548	729	431	1,545	727	464	1,530	642	497
	737 MAX	187	52	0	338	187	0	473	330	3
	757-200/-300	140	100	18	130	88	23	120	77	27
	A320ceo	2,143	972	489	2,065	854	487	1,983	878	477
	A320neo	351	142	1	549	209	8	737	333	20
	MD-80/-90	16	11	2	13	10	2	11	9	1
Europe Total		**4,655**	**2,144**	**963**	**4,882**	**2,228**	**1,002**	**5,069**	**2,369**	**1,040**
Middle East	727-100/-200	4	1	1	3	1	0	2	1	0
	737 Classic	26	15	4	24	10	3	21	12	2
	737NG	159	67	51	161	68	60	162	61	69
	737 MAX	53	20	0	85	53	0	118	80	2
	757-200/-300	6	4	1	6	6	0	6	3	1
	A320ceo	393	170	85	384	173	91	374	166	95
	A320neo	96	39	0	135	57	0	186	78	1
	MD-80/-90	25	16	3	19	15	2	16	13	2
Middle East Total		**763**	**332**	**145**	**818**	**384**	**157**	**886**	**416**	**171**
North America	727-100/-200	15	6	0	11	5	0	8	3	0
	737 Classic	69	43	5	63	29	4	58	36	5
	737NG	1,971	901	562	1,939	859	560	1,889	799	629
	737 MAX	179	92	0	294	179	0	441	270	8
	757-200/-300	402	270	67	377	204	69	354	233	64
	A320ceo	1,299	604	243	1,278	580	251	1,224	561	277
	A320neo	173	65		279	107	3	397	169	10
	MD-80/-90	178	111	25	142	101	12	122	91	5
North America Total		**4,287**	**2,093**	**902**	**4,384**	**2,063**	**897**	**4,492**	**2,161**	**997**
South America	727-100/-200	18	12		13	2		9	6	
	737 Classic	78	47	7	70	39	6	62	26	3
	737NG	352	148	134	359	149	140	364	161	146
	737 MAX	71	28		101	71		132	99	1
	757-200/-300	10	8	1	11	8	2	11	6	2
	A320ceo	566	249	124	560	246	123	551	231	131
	A320neo	182	95		257	87	4	328	165	13
	MD-80/-90	22	16	2	18	12		15	11	1
South America Total		**1,299**	**603**	**269**	**1,388**	**615**	**276**	**1,473**	**706**	**297**
Grand total		**17,554**	**8,136**	**3,680**	**18,508**	**8,472**	**3,890**	**19,425**	**9,102**	**4,182**

The new 737 MAX fleet has entered service with a targeted 15,000FH/36MO base check cycle. This is an extension on the current legacy aircraft base check cycles of 18MO and 24MO.

A320 family CEO

The A320ceo entered service in 1988, followed by the A318, A319 and A321 family members.

The A320 MSG-3 MPD is a complex document covering the family of aircraft and different modification statuses listing task intervals expressed in FH, FC, and calendar time.

The basic interval for light or 'A' checks is 750FH, 750FC, or four months, whichever interval is reached first. Several groups of tasks have intervals that are multiples of this basic 'A' check interval.

The basic interval for the 'C' check is 7,500FH, 5,000FC or 24MO, whichever is reached first. There are several groups of tasks whose intervals are multiples of this basic 'C' check interval, which has been extended several times over the life of the MPD.

A large number of tasks within the MPD can be considered as out of phase (OOP), meaning they will fall between the larger task group intervals. These will need to be managed into the C check packages. The number of OOP tasks depends on individual aircraft utilisation.

The highest annual FH utilisation aircraft is an A320 with 5,969FH with 3,432FC. This equates to 1.7FH per FC on average.

The highest annual FC utilisation aircraft is also an A320 with 4,902FC and 4,656FH. This equates to 0.95FH per FC on average. Such a high annual FH and FC utilisation would bring forward the C checks earlier than the calendar backstop of 24MO.

Of the larger fleets of A320s and A321s, average annual utilisation of mainline and low-cost passenger fleets is 3,000FH and 1,600FC for the A320, and 2,900FH and 1,350FC for the A321. This works out at FH:FC ratios of 1.9:1 and 2:1 respectively.

The A320ceo family in-service fleets are A318 (60), A319 (1,361), A320 (4,193), and A321 (1,634). There are no A320 family freighters to date, but modifications are being designed.

Of the fleet, 105 are Airbus Corporate Jets (ACJ). Unlike Boeing's BBJ, the Airbus business jet uses the same MPD as the rest of the family.

A320 family NEO

The A320neo entered service in January 2016, and the A321neo in May 2017.

The in-service fleet is growing daily. In this snapshot of the fleet in October 2018, there is a single A319 plus 388 A320s and 82 A321s. There are 10 neo aircraft listed as stored, of which two are with Airbus and eight with operators.

The highest annual FH utilisation aircraft is an A320neo with 4,547FH and 1,402FC. This equates to 3.2FH per FC.

The highest annual FC utilisation aircraft is a A320neo with 2,682FC and 3,867FH. This equates to 1.4FH per FC.

The average annual fleet utilisation information available for the aircraft that entered service in 2016 and 2017 is 2,771FH and 1,498FC, which equates to a ratio of 1.8FH:1FC.

The A320ceo and A320neo family of aircraft share the same MPD inspections with tasks solely applicable to the neo fleet so listed in the applicability section for each maintenance task.

MD-80/-90

The MD-80 entered service in 1980 and production ceased in 1999. The MD-80 series has a maintenance programme based on MSG-2 principles.

The MD-90 entered service in 1995 and production ceased in 2000. The MD-90 has a maintenance programme conceived on MSG-3 principles. There were options for the MD-80 operators to transfer to an MSG-3 programme.

The MSG-2 programme followed by most MD-80 operators required a C check interval at 4,800FH or 18MO, whichever is reached first. There is also an intermediate check at an interval of 16,000FH or 66MO, and then a D check at 30,000FH or 120MO.

The MSG-3 programme for the MD-90 requires A checks at an interval of 550FH and P checks (similar to C checks) at 4,000FH. There is also a separate group of structural tasks with intervals of 60MO, 90MO and 120MO.

Most of the 336 remaining MD-80/-90 series fleet in service are passenger aircraft. Only 13 MD-80s are freighters.

The highest annual FH utilisation aircraft is an MD-80 with 3,107FH and 1,568FC. This works out at an FH:FC ratio of 2:1. Such a high FH utilisation will result in the aircraft being close to reaching FH thresholds before the calendar limit for a base check.

The highest annual FC utilisation aircraft is an MD-80 with 3,033FC and 1,784FH. This works out at an FH to FC ratio of 0.6:1.

The average annual fleet utilisation

information available is 1,978FH and 1,457FC, equalling a rate of 1.4FH per FC, putting the fleet within the normal parameters for base checks.

The MD-80 series fleet has the highest number of stored aircraft of the narrowbody fleet. The average age of stored aircraft is almost 28 years.

727

The 727 entered service in 1964 and production ceased in 1984. Most of the fleet still in service are now configured as freighters. The oldest aircraft are over 50 years of age. Such a length of service means the aircraft's maintenance programmes will have been though many evolutions.

Modern maintenance programmes have been developed using MSG-3, while legacy maintenance programmes personalised to the individual role of the aircraft are also found.

The 727's MSG-3 maintenance as a guide says the 'A' Check is to be carried out at intervals not to exceed 600FH.

The 'C' Check is to be accomplished at intervals not to exceed 4,000FH or 24 MO, whichever comes first.

Interestingly, it is one of the few MSG-3 MPDs that still lists 'C' check references against the inspection task.

With the older pre-MSG-3 maintenance programmes 'A', 'B' and 'C' check intervals will often be referenced in calendar time, while C checks can be referred to as packages: 'P-1', 'P-2', 'P-3' and so on. Approved maintenance programmes for the 727 vary more than any other type.

There is not a large amount of recorded annual utilisation data available for the 727. Notable statistics from the fleet, however, include an average age now of 40 years.

The highest annual FH utilisation is a 727-200 in passenger configuration with 2,956FH and 2,225FC. This works out at a rate of FH to FC ratio of 1.3:1.

The highest annual FC utilisation aircraft is a 727-200 military multi-role (utility transport), at 2,531FC and 1,481FH. This works out at an FH:FC ratio of 0.6:1.

As many of the fleet listed do not show utilisations the aircraft are likely to be flying longer sectors.

Base maintenance market

Consulting company ICF specialises in MRO advisory services in its aviation and aerospace division, as well as other services that include comprehensive strategy, market research, market analysis, and maintenance benchmarking.

ICF Consulting generates annual estimates of the number of C and HMV airframe checks for the global regional, narrowbody and widebody fleets from their own proprietary MRO forecast model. It subdivides these into the number of C and HMV checks for each main aircraft type. A sample of this is shown *(see table, page 34)*.

For reference, the HMV numbers are a sum of any check higher than a C4, including structural checks. Grouping checks by the same title can be difficult, especially for MSG-3 maintenance programmes, because each operator can group and title work packages differently.

As previously detailed, base check programmes generally have a C check interval of close to 24MO for most passenger aircraft, 18MO for various legacy aircraft and some freighters, and 36MO for the newer aircraft in service. Structural checks occur near or at 6YE and 12YE. These check intervals are used as an overview without over-simplifying the MSG-2 or MSG-3 driven maintenance programmes.

As an example of the current narrowbody fleet check size, ICF estimates that through 2018 there will be a requirement for a total of 7,614 C check slots and 3,470 HMV slots, up from 7,423 C checks and 3,260 HMV checks in 2017. These figures are based on a rise in total fleet numbers from ICF's database from 15,622 in 2017, to 16,592 in 2018 *(see table, page 34)*.

In terms of number of checks per

The narrowbody fleets are maintained against a wide range of MSG-2, MSG-3, and bespoke personalised maintenance programmes.

aircraft type, the table indicates that for legacy aircraft on check cycles of 24MO, such as the 737-NG, about 50% of the in-service fleets require a C check every year and about 30% of aircraft require a HMV check.

The MD-80s that remain on the 18MO programme, for example, would account for the higher C check requirement figure of more than 65% per year.

For rapidly declining fleets, such as the 727, predicted C checks per year are closer to 33% of the fleet numbers.

There are many factors that affect when an aircraft may undergo its 'next due' maintenance requirements. These include lease handbacks that can bring checks forward, or the entry into storage that can delay a check.

ICF also evaluates the narrowbody fleet checks per global region *(see table, page 36)*. The table also indicates the predicted size of the check market per aircraft type up to and including 2021.

The highest number of base inputs by 2021 are in the Asia Pacific region, with 3,168 C checks and 1,545 HMVs predicted.

The second-highest number of base inputs by 2021 are in Europe, with 2,369 C checks and 1,040 HMVs predicted.

North America is third-highest with 2,161 C checks and 997 HMV checks predicted, and South America is the fourth-largest market with 706 C and 297 HMV checks per year by 2021.

There is also a growing number of slots required in MROs over the next three years per region for new aircraft types such as the MAX *(see table, page 36)*. In Europe, for example, the increase in number of C checks is from 187 in 2019, to 330 in 2021. For the new-to-service type, the first HMV visits will increase rapidly from 2023 onwards.

Regional or narrowbody?

Aircraft development activity is high across regional, narrowbody and widebody fleets. Two new entrants bordering both the regional and narrowbody markets in terms of size and seating capacity are the Embraer E190-E2 and E195-E2, and the Bombardier CSeries. The latter is now titled the Airbus A220-100 and A220-300.

Seat capacity for the larger E195-E2 in single-class configuration is guided at 132-146. The larger A220-300 has a single-class seating range listed as up to 160 seats. This puts their passenger capacity in the same market as other smaller narrowbody aircraft. A 737-700, for example, has a single-class capacity of 140 seats. The A220-300 has a similar configuration to a 737-400 or MD-80.

For this article, due to the new aircraft's low fleet numbers and the long period before first maintenance visits are due, fleet details have not been included in the constructed tables.

Additionally, the specialist MRO market for Embraer- and Bombardier-based fleets is traditionally separate from MROs targeting the large fleet numbers of the legacy Boeing and Airbus fleets. To acknowledge the two new aircraft, however, a brief overview of their current fleet size, orders and maintenance requirements follows here.

For details on the regional E-170/-175/-190/-195 Embraer fleet sizes and C Check market, see 'The regional aircraft maintenance market, Aircraft Commerce, June/July 2017, page 65.'

The Embraer E2

The new E2s of the Embraer fleet are the E175-E2 (yet to enter service), E190-E2 and E195-E2. The two larger of the models, the E190-E2 and E195-E2, entered service late April 2018.

The current E190-E2 fleet numbers include three for Wideroe, based in Norway, and four still with Embraer. Two E195-E2s are listed in service with Embraer.

Orders for the types are E175-E2 (100), E190-E2 (58) and E195-E2 (94). These orders are from all global regions. Operators with large orders include SkyWest Airlines (100), AerCap (42) and Azul (36).

The E2's starting intervals for 'A' checks are based at 850FH, and 'C' checks at 8,500 FH. Individual operator utilisation of the fleet will impact when the base checks are due. It is estimated to be 24-36MO, unless FC or FH threshold tasks are reached first.

A220 (C series)

The A220-100 and A220-300 entered service in 2016.

The A220-100 (formerly CS100) has more than 14 aircraft in service. SWISS has eight, and several are still with Bombardier.

The A220-300 (formally CS300) has over 39 aircraft in service across three operators: airBaltic (12), Korean Air (8) and SWISS (17). Bombardier has two listed as in service.

Orders for the type are for the -100 (115) and the -300 (242). These orders are from all regions apart from South America.

Operators with large fleets on order include Delta Air Lines (75), Air Canada (45) and airBaltic (38). Other large orders are with leasing and finance companies, such as Macquarie AirFinance (40) and Republic Airways Holdings Inc (40).

'A' and 'C' check intervals of 850FH

and 8,500FH are also indicated for the type, confirming longer-than-standard initial intervals for the new release aircraft.

Retirement trends

Retirement trends of each aircraft types will impact future maintenance predictions.

The legacy 727, 737 Classic, 757, and MD80/90 fleets are naturally declining.

Introduction of the 737MAX and the A320neo families will see 737 NGs and A320ceo moving around the market to new operators, as well as retirements of the older aircraft in the fleet.

While factors, such as fuel burn, aircraft technical age, low yields, and expiring lease agreements, are the main reasons for aircraft retirements, another is consumer-driven. New technology is easier to sell.

This is why passenger aircraft are generally retired before freighters, although if residual value of the aircraft is too high retirement is likely to be delayed.

Reaching each aircraft's Limit of Validity (LOV) or Design Service Goal (DSG) can also result in retirement. To address widespread fatigue damage (WFD), OEMs were required to introduce LOV for the engineering data that supports the structural maintenance programme of each aircraft type. Once the limit is reached the aircraft is to be removed from service.

A summary of the last three years of retirements per fleet type follows:

The 737 Classic aircraft fleet with a change of status from in-service to retired was 64 units in 2016, 67 in 2017, and 24 up to October 2018. The average age at retirement has been 26 years.

The 737 NG fleet with a change of status to retired was 22 units in 2016 (all 737-700), 31 in 2017, and 20 up to October 2018. Most of the aircraft have been retired at just under the age of 20 years.

The 757 aircraft fleet with a change of status to retired was 59 units in 2016, 63 in 2017, and 16 up to October 2018 (all 757-200). The average retirement age has been near 30 years of age. Of the retired aircraft, only 21 were freighters.

The A320ceo family fleet with a change of status to retired was 45 units in 2016, 68 in 2017, and 36 up to October 2018. Just over 50% are more than 20 years, with the oldest at 30.5 years. The youngest retired aircraft is listed at eight years old.

The MD-80/-90 series aircraft fleet with a change of status to retired was 52 units in 2016, 66 in 2017, and 76 up to October 2018. The average retirement age is almost 28 years.

Summary

While the narrowbody fleet size and check requirements have been examined, what must be considered beyond the 2021 statistics are the new challenges facing all airframe MROs.

While the number of total checks per year increases due to larger fleets, MROs still have to secure the work against competitors. Many airline-based MROs also rely on third-party work.

To do so, MROs must prepare for new fleets of highly sophisticated aircraft with longer maintenance intervals and reduced work content that are overtaking the market. This must be recognised along with increased interest of OEMs in taking a greater percentage of the airframe aftermarket support.

MROs are also having to adapt to the big data evolution. Aircraft data-producing capabilities and the industry's digitisation of all possible information is assisting development of predictive and preventative maintenance programmes. It will be interesting to see how these will affect aircraft maintenance programmes and check frequencies over time. AC