Several factors have compounded to produce a surge in the shop visit activity of CFM56-5B, CFM56-7B and V2500 engines over the past three years. Engine maintenance providers have faced difficulties with rising demand, as shop visit turnaround times have increase by up to 50%.

CFM56-5B/-7B & V2500 experience surge in shop visit activity

The past few years have seen a steady increase in the most numerous narrowbody engine types. The increase in shop visit (SV) activity has been triggered by a culmination of events and factors. The result of this surge in the CFM56-5B/-7B and V2500 aftermarket has led to an increase in SV turn times and a backlog of engines requiring maintenance, and a subsequent shortage of maintenance capacity and of serviceable and time-continued engines for operation. It has also led to an increase in engine values and lease rates.

Fleet profile

The 737NG and A320 current engine option (ceo) families have dominated the narrowbody market, in particular since 757 production ceased in 2005. Combined production rates of A320s and 737NGs have been as high as 931-984 units per year in 2013-2016.

These two families are now near the end of their production runs, with the introduction of the A320 new engine option (neo) being phased in while the last 90 or so A320ceos are built before production ends in late 2019 or early 2020. Similarly, 737 MAX deliveries started in mid-2017, while 737NG production continues. The ramping up of 737 MAX production, while fulfilling the last 737NG orders, has been disrupted by the grounding of the 737 MAX in March 2019. It is not clear when the 737 MAX may be certified to recommence operations.

The A320neo has experienced some disruptions to production. One problem has been technical issues with the Pratt & Whitney (PW) PW1100G, one of the engine types powering the A320neo family. These include reliability problems with the engine's combustor. There have also been a few technical issues with the A320neo's other engine, the CFM LEAP-1A.

The problems with the A320neo and 737 MAX programmes have led to continued production of the A320ceo and 737NG, which has affected the availability of engines, and related components and parts in the aftermarket.

The active fleet of A320ceo and 737NG family aircraft comprises 13,950 aircraft, including business jet and some military variants *(see table, page 28)*. This is divided between 4,170 CFM56-5A/-5B-powered aircraft, 3,040 equipped with V2500 engines and 6,740 737NGs equipped only with the CFM56-7B. The 10,910 aircraft with CFM5-5B and -7B engines therefore have 21,820 installed engines plus up to 3,150 spare units to provide support. There are another 6,080 installed V2500 engines, plus 900 spare units.

Each of the three main families is divided between several variants that have a range of thrust ratings. All three main engine types have generally achieved long removal intervals between SVs. This is especially the case with the CFM56-7B which has a high exhaust gas temperature (EGT) margin.

"These high margins have meant that many of the engines in the fleet can be managed with respect to life limited parts (LLP) expiry, rather than removal because of EGT margin erosion and degradation," says Nick Hankins, senior engineer at Jet Engine Management. "Most variants in the CFM56-5B, V2500 and CFM56-7B families are capable of long removal intervals, which last up to the full life of LLPs in at least some modules of the engine. The exceptions to this are the higher-rated variants with lower EGT margins, or engines operated in hot environments where EGT margin erosion and degradation rates are higher than those experienced in temperate climates."

The split of the fleet of each engine type into variants according to thrust rating affects removal intervals, and therefore the likely number of annual SVs for the overall fleet.

CFM56-5A/-5B

The CFM56-5A and -5B families can be divided into five groups. The CFM56-5A1/3/5 are rated at 23,500-26,500lbs thrust. This fleet is relatively small at 301 aircraft *(see table, page 28)*.

The CFM56-5B series includes eight variants, rated at 21,600-32,000lbs. The second group of 53 aircraft is the small A318 fleet, powered by the -5B8, rated at 21,600lbs.

The third group are the -5B5, 6 and 7 variants rated at 22,000-27,000lbs. These power 762 A319s *(see table, page 28)*.

The fourth group is the -5B4 and 5B6 rated at 23,500lbs and 27,000lbs. They equip 2,390 active aircraft. These lower rated -5B series engines all have relatively high EGT margins, and when new are 110-180 degrees centigrade.

The three CFM56-5B variants with the highest thrust ratings are the -5B1, 2 and 3 at 30,000-32,000lbs. These engines power 670 aircraft and have initial EGT margins of 66-115 degrees, so they have removal

CFM56-5B, CFM56-7B & V2500 FLEET SUMMARY

Engine model	Aircraft type	Number active aircraft	Annual FC	FH:FC ratio
CFM56-5A1/3/5	A319/20	301	1,455	1.95
CFM56-5B8/9	A318	53	2,145	1.10
CFM56-5B5/6/7	A319	762	1,773	1.65
CFM56-5B4/6	A320	2,390	1,764	1.79
CFM56-5B1/2/3	A321	666	1,425	2.17
TOTAL CFM56-5A/5B		**4,172**		
CFM56-7B20	737-600/-700	113	1,854	1.65
CFM56-7B22	737-700	641	1,954	1.56
CFM56-7B24	737-700/-800	346	1,652	1.84
CFM56-7B24/3	737-700/-800	245	1,582	1.93
CFM56-7B24E	737-700/-800/-900	564	1,613	1.89
CFM56-7B26	737-800/-900	904	1,463	2.08
CFM56-7B26/3	737-700/-800/-900	830	1,612	1.93
CFM56-7B26E	737-800/-900	2,123	1,493	1.42
CFM56-7B27	737-800	180	1,385	2.41
CFM56-7B27/3	737-800/-900	796	1,460	2.52
TOTAL CFM56-7B		**6,742**		
V2500-A1	A320	31	1,415	2.00
V2522-A5	A319	115	1,562	1.67
V2524-A5	A319	235	1,814	1.63
V2527-A5	A319/20	738	1,588	2.04
V2527-A5 SelectOne	A320	765	1,832	1.92
V2527-A5 SelectTwo	A320	155	1,787	1.93
V2530-A5	A321	23	1,698	1,30
V2533-A5	A321	228	1,562	1.97
V2533-A5 SelectOne	A321	433	1,384	2.50
V25330A5 SelectTwo	A321	313	1,538	2.24
TOTAL V2500		**3,036**		
OVERALL TOTAL		**13,950**		

intervals that are mainly related to EGT margin loss. The actual margins depend on thrust rating, and build status with respect to modification programme.

The CFM56-5B series has had three major modification programmes. The first of these was the /P upgrade in 1996, which was an improved build standard that increased EGT margin by about 10 degrees centigrade.

The second modification package was referred to as the Tech Insertion upgrade; engines are denoted by a /3 suffix. It was available from 2007, and achieved a further increase in EGT margin of five to 10 degrees centigrade.

The two main factors driving these removal intervals are EGT margin erosion and LLP life limits. The CFM56-5B has four main modules, each with LLPs that are close in life limits. The fan and HPC module has three LLPs with lives of 30,000 engine flight cycles (EFC), the HPC and HPT modules have nine parts with lives of 20,000EFC, and the LPT has six parts with lives of 25,000EFC.

The potential first removal interval of most -5B variants, as allowed by EGT margin, is thus close to the 20,000EFC limit of the core engine parts.

CFM56-7B

The CFM56-7B series has five variants rated at 20,600-27,300lbs of thrust. The -7B's main feature is that it used the core of the -5B series designed for thrusts up to 32,000lbs, but was de-rated with a smaller fan. Consequently the variants all have relatively high EGT margins.

Like the -5B series, the -7B had a series of modification and upgrade programmes that featured hardware and component improvements. The baseline engine configuration incorporated the /P modification and upgrade that was developed for the -5B series in the mid-1990s.

The initial EGT margins are as high as 130 degrees centigrade for the -7B20, and 100-110 degrees for the -7B24. The -7B24 has a margin of 100-105 degrees, and the -7B26 also has a relatively high initial margin of 80-85 degrees centigrade. Only the -7B27 has a relatively low initial margin of 55 degrees. The margins of /p and /3 engines are a few degrees higher.

A high-rated -7B27 engine, with the original build specification, may therefore achieve an interval of up to 11,000EFC. A -7B26 can achieve up to 13,000EFC, and a -7B24 in the region of 16,000EFC. The two lower-rated variants can achieve intervals of up to 20,000EFC.

These potential removal intervals have to be considered in relation to the LLP life limits. Parts in the fan/LPC have target lives of 30,000EFC, parts in the LPT have target lives of 25,000EFC, and LLPs in the two core modules have lives of 20,000EFC.

The -7B20, -7B22 and -7B24 can therefore remain on-wing for the lives of the two core module LLPs.

V2500-A5

The V2500-A5-powered fleet is the smallest of the three main types, with about 3,030-powered aircraft in active service *(see table, this page)*. There are five variants with thrust ratings of 23,000lbs, 24,500lbs, 26,600lbs, 30,400lbs and 31,600lbs.

The two most popular variants are the V2527-A5 rated at 26,600lbs, which powers 1,660 aircraft; and the V2533-A5 rated at 31,600lbs, which powers 974.

The two lowest rated -A5 variants have initial EGT margins of 90-115 degrees centigrade, while the most dominant V2527-A5 had an initial EGT margin of 70-80 degrees. The V2533-A5 had an initial EGT margin of 40-60 degrees centigrade.

The SelectOne upgrade includes improvements to HPC, HPT and LPT hardware, and has a higher initial EGT margin of 12 degrees centigrade. More than 1,200 A320 family aircraft were built with SelectOne engines up to 2017. EGT margins for the V2527-A5 engines were increased to as much as 90-100 degrees, while V2533-A5 engines had margins of 70-80 degrees.

The V2522-A5 and 24-A5 have erosion rates of 3.7 degrees per 1,000EFC, and are capable of intervals in excess of 24,000EFC.

The V2527-A5 experiences EGT margin erosion rates of about 5.0 degrees per 1,000EFC, so original build standard engines can remain on-wing for 14,000-19,000EFC. SelectOne engines could remain on-wing close to 20,000EFC for the first removal.

The highest-rated variant rated at 31,600lbs has an EGT margin erosion rate of 10 degrees per 1,000EFC. Engines can therefore achieve intervals of 4,000-8,000EFC, depending on initial EGT margin.

Shop visit patterns

The main issue with respect to the number of annual SVs across the industry is that most variants are capable of first-run removal intervals close to the first LLP life limits of 20,000EFC. "This is particularly the case with CFM56-7B series engines. Except the highest-rated variant, the first run intervals of -7Bs are long enough for engines to be managed around their LLP life limits," says Hankins. "This contrasts to the usual system of managing with respect to EGT margin, and its erosion, in the case of most engine types. The same applies to most -5B variants.

"The only cases where EGT margin is the main removal and maintenance management driver are with the highest-rated variants and in hot environments," continues Hankins. "Despite this, even some airlines in the Middle East have had good experience, even though they still suffer hardware deterioration."

The ability of engines to reach first removal intervals close to LLP life limits poses a management dilemma in the case of some engines. "While the V2500-A5 has uniform LLP lives of 20,000EFC, meaning all modules will have a full SV and LLP replacement, the CFM56-5B and -7B have LPT life limits of 25,000EFC," continues Hankins.

"Also, the life limits on fan/LPC parts are 30,000EFC. One choice for airlines at the first SV is to build engines to last up to the LPT life limits. For most engines this is at least 5,000EFC, and up to 10,000EFC. In this scenario, core engine LLPs would be replaced, while other LLPs are left in the engine. The second choice would be to replace both core and LPT parts, and perform an SV workscope for the engine to remain on-wing to the fan/LPC life limits of 30,000EFC. This would be at least 10,000EFC and up to 15,000EFC," Hankins explains.

While the V2500 has uniform LLP lives, Archer makes the point that its medium- and higher-rated variants can get their LLP and SV management compromised by their removal intervals.

One particular feature of the recent surge in SV activity is that the long intervals achieved by many engines equate to long calendar periods between SVs. This has caused a delayed surge in SV activity that many were expecting for several years.

Most aircraft achieve 2,600-3,400FH and 1,400-1,900FC per year. The removal intervals of 19,000-20,000EFC for the best engines are thus equivalent to 10-14 years of operation. The highest-rated engines with removal intervals of 6,000-7,000EFC in the case of the V2533-A5, and up to 15,000EFC in the case of the CFM56-5B1/2/3 powering the A321 will be removed for their first SV at four to 10 years of operation.

Similarly, the CFM56-7B27, which has the highest initial EGT margin of the highest-thrust variants of the CFM56-5B, CFM56-7B and V2500-A5 families, will be removed after about eight years.

The first SVs are mainly affected by these long calendar intervals. Despite the fact that some engines will have early unscheduled removals, and a fraction of the fleet will have shorter-than-average removal intervals, most engines on the CFM56-5B- and CFM56-7B-powered fleets will not undergo their first removals until after eight or nine years in service.

The implications are that SV numbers for the first-build -5B and V2500 engines would not reach significant numbers until 1996-1997; eight years after the first A320ceos entered service. First removal SV activity would then follow an approximate eight-year lag in annual production, but remain low for an extended period.

"The surge in SV activity over the past two years is mainly due to a steady rise in the number of engines going through their first SV coinciding with older engines going through their second and third SVs. Some engines are even going through their fourth," says Hankins. "This is a different situation from five to 10 years ago."

Most engines going through their first scheduled removal and SV will have been produced from 2007 to 2011. This is reflected by David Green, vice president airline & fleets at StandardAero. "More than 50% of the 23,000 or so CFM56-5B and -7B engines have yet to go through their first SV, and another 35% have only been through one. The number of SVs for these two engines exceeds 2,000 per year. This figure is projected to continue rising through to the middle of the 2020s, depending on the availability of materials and parts."

Peak production rates were 984 aircraft in 2015, equivalent to almost 2,000 installed engines. Most of these are expected to go through their first removals from 2023 to 2026.

A320neo & 737 MAX

In addition to practical issues relating to the CFM56-5B/-7B and V2500, other external factors have also had an effect. Production of the A320neo and 737 MAX commenced at similar times, and was expected to reach significant levels in 2019. "The production of A320neo family types has faced several delays, so numbers have not quite reached originally planned levels," says Hankins. "There have been issues relating to engine production. The PW1100G has had several technical problems, including with the combustor. There have been other durability problems. This has delayed and reduced deliveries of new aircraft.

"The grounding of the 737 MAX in March 2019 has meant that 737NGs have been kept in service for longer, and the production of A320ceos and 737NGs has been extended," continues Hankins. "The relatively low fuel price during 2019 has helped prolong the use of A320ceos and 737NGs."

Airbus in turn required continued production of the CFM56-5B, which apparently affected the availability of material for use in shops maintaining the engine.

Shop visit activity

The multiple factors affecting the CFM56-5B/-7B and V2500 have resulted in a surge in their SV activity in recent years. "The number of SVs is expected to keep increasing up to 2024, given the build profile of the related aircraft types, and the intervals to first engine SV," says Alun Roberts, vice president of engine leasing and trading at AJW.

One issue that may limit the increase in maintenance activity is the possible retirement of several hundred A320ceos and 737NGs as more A320neos are delivered, and the 737 MAX is returned to service in late 2019 or early 2020. Despite the grounding, Boeing has continued to build 737 MAX aircraft, and placed them

The number of annual shop visits for the CFM56-7B reached about 1,850 in 2018. Activity is forecast to reach another peak in 2020, and again between 2023 and 2026.

into storage.

A peak in SVs is predicted in 2021 and again in 2023-2025. The level of activity for the three main engine types reached about 3,500 SVs in 2018: 610 SVs for the CFM56-5A/-5B fleet; 1,050 for the V2500; and almost 1,900 for the CFM56-7B.

This is an increase from a total of 2,800-2,900 SVs for these three engines in the 2014-2015 period. The 2018 level for the CFM56-7B is a 25% increase from about 1,400 maintenance events in 2014.

The number of SVs for the CFM56-7B is not expected to reach this level again, but is expected to surge in 2020, and again in 2023 and 2026. A similar pattern is expected for the V2500, although the highest peak is forecast for 2020. The number of maintenance visits for the CFM56-5A/-5B is forecast to reach 820 in 2019, and then climb to 910 in 2022, after dipping in 2020.

The overall annual SV market is therefore expected to remain at 3,400-3,700 until 2025, after which it should gradually decline to 3,000 per year and fewer after 2027. This decline will be mainly due to the fleet shrinking, with production of both main types ceasing in 2019 and 2020.

"The recent surge in SV activity has caused a considerable increase in demand for engine material," says Roberts. "The first issue with this surge is that it has been compounded by factors such as the simultaneous occurrence of first, second and mature SVs in recent years. This has then been compounded by the unexpected continued operation of relatively large numbers of A320ceos and 737NGs. This is partly explained by reduced deliveries of new generation narrowbodies, but also by economic circumstances that have led to continued demand for aircraft. The problem of life extensions for these aircraft will relax in four to five years. There will, however, always be a demand for these older engines from certain airlines. A high portion of both A320ceo and 737NG fleets is expected to be converted to freighters, and so have extended service."

Shop visit delays

The first main result of the surge in engine shop activity is that it has become difficult in recent years to find an available maintenance slot. "In many cases the waiting time for a slot is six to eight months," says Roberts. "This is not just because of the demand for maintenance. The lack, or slow supply, of material for engine SVs has increased the turn time from the usual 70-80 days to 110-120 days. It is not abnormal for engines to be stuck in shops waiting for material. These delays have therefore reduced the number of effective slots at engine shops. The knock-on effect has been to lengthen the waiting time for maintenance slots.

"AJW performs a lot of engine management services, and we have to find maintenance slots as part of this activity," says Roberts. "This has been helped by the slight reduction in V2500 SV activity over the past six months.

"The poor parts and material availability stems from the engine OEMs. The capacity issue of engine shops goes right down to the part number (P/N) level," says Brendan McIntyre, head of engine material at AJW. "The parts that have caused the biggest problems include the fan blades, which have a 90-day lead time. The high scrap rate of fan blades has lengthened lead times overall."

In addition to a slow supply of parts, engine shops have also delayed investment in tooling, equipment and skills. "This delay or reluctance to invest is explained by the bow wave of engine SV activity failing to materialise for successive years," says Hankins. "This especially relates to the -7B, not only because it is the largest fleet, but also because it achieves very long removal intervals. These shortages are actually causing some shops to stop taking further engine inductions. The current surge in engine maintenance activity seems to have taken the aftermarket by surprise."

One effect of this has been for airlines to send engines further around the world to shops with a limited amount of capacity. Examples are airlines in South America sending engines to Europe.

"The engine shops are limited by four main factors," says Roberts. "These are the number of slots they have available per year, the rate of supply of material from the engine OEMs, the infrastructure within the shop, and the rate at which parts can be repaired. There have also been other smaller but contributory issues, such as an airworthiness directive (AD) on the -7B. This was actually expected to cause a surge in maintenance activity, which did not actually materialise."

These problems clearly raise the issue of how much longer the aftermarket will have to wait until capacity is increased, and turn and waiting times start to fall. "The issue of parts supply should be rectified within eight months," estimates Hankins. "With the current problems, engine shops will have to invest in capacity and infrastructure. This can be justified given the forecasts of an annual increase in global SV activity that is predicted to peak in 2021 and last up to 2026. Moreover, the market for these engines will continue for a further 20 years."

Roberts says to avoid SV delays, maintenance providers will need to pre-plan workscopes and have all the predicted required parts in place about one month in advance. One of the factors leading to the slow supply of parts and lack of infrastructure has been the strategy of minimal levels of investment that engine shops have followed over an extended period. With the predicted surge of engine SV numbers constantly failing to materialise, engine shops have been ordering parts on a just-in-time basis.

The CFM56-5B and -7B, and V2500 are not the only engines to have experienced an increase in SV activity. "There has also been a considerable increase in maintenance activity among several widebody engine types," says Roberts.

Aftermarket effects

There are several consequences of the surge in SV activity of these engine types. The first clear effect has been the increased demand for time-continued engines from airlines, while they await SV slots; and from traders and lessors, for the purposes of tearing down engines to extract LLPs and parts.

"There has been a considerable increase in the market values and lease rates of these three main engine types," says Roberts. "For example, the V2500 was hard to lease in 2015 and 2016, and a lessor could expect $80,000 per month for the engine and maintenance reserves. Recently lease rates have climbed to $80,000 per month for just the engine. A further $80,000 per month has been charged for the maintenance reserves, so the rates have effectively doubled over the past three to four years.

"Moreover, there has been little or no availability of CFM56-5Bs over the past 18 months, and lessors are able to command $90,000-100,000 per month for them, on the basis of a lease for at least 12 months," adds Roberts. "Also, the -7Bs have recently been leased out at rates of about $75,000 per month for two-year leases. The fact that engines are being leased for this length of time illustrates the appetite in the market."

The market for tearing down engines with remaining maintenance life has become profitable and competitive. "There is little sense, however, in dismantling engines with just 3,000-5,000EFC maintenance time remaining," says Hankins. "Engines with this amount of maintenance life are more likely to be leased by airlines to provide support while they wait the additional time for maintenance slots and added turn times. An interesting development is that lessors are prepared to take back engines off-lease in an as-is condition. The teardown of these engines is thus generating a supply of used serviceable material (USM) parts." The lower-thrust variants in particular are the engines worth parting out, since they provide good quality parts and material.

Much of the shortage of parts, however, is related to LLPs. As a result, tearing down engines with a few thousand EFC remaining is not really helping the market, because engines are capable of long on-wing intervals, so there is little interest in LLPs with a few thousand EFC in remaining lives. There is, however, demand for USM for engines going into their second, third and fourth SVs. This will mainly be for parts in the cooler modules. "Many HPT blades now have soft lives, as recommended by the OEMs, and so do not get repaired. The soft lives are mainly, however, in the 20,000-25,000EFC range, but it depends on the P/N of the blade. This number of cycles means the parts will last the first SV interval, and possibly the second interval," says Hankins.

Maintenance capacity

This shortage of engines with maintenance life and extended waiting times will ultimately have to be resolved by increasing maintenance capacity.

"One factor that will help is that the production runs of the A320ceos and 737NGs are both close to finishing," says David Archer, senior engine analyst, at The IBA Group. "The cessation will then help the supply of parts and materials for the CFM56-5B and -7B, and V2500. The number of forecast SVs means that shops will have to extend their capacity for these types."

Several shops have made efforts to increase their annual throughput capacity, in response to the steady climb in demand

The V2500 experienced a peak of about 1,050 shop visits in 2018. Shop visit activity is forecast to reach an even higher peak of about 1,300 in 2021, and remain high until about 2025.

from 2014. "StandardAero has shops for the CFM56-7B, and has a achieved a continuous ramp-up in CFM56-7B output capacity since 2010," says Green. "The current challenges of tight material and parts supply have significantly limited our ability to match growth in demand with our maintenance capacity. Nevertheless, our CFM56-7B inductions in 2018 were up 33% comparted to 2014. Moreover, the number of SVs we perform each year for the CFM56-7B will increase, depending on material availability. This is a key factor in determining annual CFM56-7B capacity."

The maturation of the CFM56-5B and -7B fleets will have several compounding effects. First, a large percentage of the fleet will go through their first SVs, and this will result in a peak in maintenance visits. MTU Maintenance says industry statistics predict 1,400 SVs for the -7B in 2019, and a peak of 1,800 SVs in 2026.

A fall from 2027 in -7B SV numbers will be due to an increasing number of 737NG retirements, with the aircraft having been in service for 30 years by then. This will not only reduce the number of engines in service, but will also increase the supply of USM and other parts. There are 33 shops globally that claim to have full capability for the -7B, and another six are planning to enter the market. Despite this, MTU Maintenance estimates that there are only actually 15 shops that offer their services to others, with the remainder being airline shops. Moreover, MTU Maintenance estimates that only 30% of the -7B market is accessible to these 15 engine shops, and this keeps the market competitive.

MTU Maintenance completes about 200 SVs per annum for the CFM56-5B and -7B. Its speciality, however, is the V2500, and it completes about 350 SVs per year. This includes the engines it has under contract for US operator jetBlue. MTU Maintenance's overall capacity for its total engine shop network is about 1,100 SVs per year, and is growing.

There are 11 major shops for the V2500 around the world. This includes shops operated by the OEM partners. These are Rolls-Royce's Glasgow shop, Pratt & Whitney's Columbus Ohio and Christchurch New Zealand shops; and IHI's facility in Japan. The other eight shops are operated by: TEM in Istanbul; MTU Maintenance, Hannover; Lufthansa Technik, Hamburg; IAI, in Tel Aviv; Evergreen in Taiwan; TS&S in Abu Dhabi; and Iberia Maintenance in Madrid. These 11 shops support the fleet of 3,000 V2500-powered A320s and about 7,000 installed and spare engines.

The overall fleet of CFM56-5Bs and -7Bs is clearly larger. Main providers of SV capacity in Europe include Air France Industries, KLM Engineering & Maintenance, Lufthansa Technik, MTU Maintenance, Aero Norway, SR Technics, TAP Maintenance & Engineering, and Iberia Maintenance. There are also the Turkish Engine Center shop associated with Pratt & Whitney, and shops operated by OEMs Safran and General Electric.

Air France Industries performs CFM56-5B SVs at its Paris Orly shop, while KLM Engineering & Maintenance performs SVs on the CFM56-7B. It has also recently added the CFM LEAP-1B to its capability. Air France Industries expects CFM56-5B and -7B maintenance to remain one capability it continues to provide, as it develops hi-tech parts repairs. It also sources USM via its trading network, while Bonus Tech in Miami has dedicated engine teardown.

Aero Norway in Stavanger has a maximum annual throughput of 120 engines per year. Rune Veenstra, chief executive officer at Aero Norway says its shop operates at about 100 engines per year in the current market, but that he expects the shop to reach about 120 engines per year in the next few years. "The annual throughput is about 70 CFM56-5B and -7B visits per year. These have increased rapidly in recent years, as activity for the -3 series has declined," says Veenstra. "Beyond 120 engines per year we would need to build a new facility. In addition, other main factors affecting capacity are tooling and staff. To ease the current situation we could use USM in SVs, but the problem is that engine values are now very high, and USM will have a short on-wing life compared to new material." In addition to the -5B and -7B, Aero Norway expects to enter the LEAP-1A/-1B market. First SVs will not start until 2024/24, and Veenstra does not expect decent volumes of SVs until 2028.

There are also shops operated by GE in the US and Brazil. Independent engine shops offering CFM56 capability include Lockheed Martin Commercial Engines Services, Global Engine Maintenance, Aerothrust, Delta Tech Ops, and MTU Maintenance Canada in Vancouver.

There are also shops operated by IAI, in Tel Aviv; and MTU Maintenance Zhuhai in China. The main shops in the Asia Pacific include Ameco Beijing, GE Aviation Services in Malaysia, GAMECO, Sichuan Snecma Aero Engine Maintenance Company.

Aerothrust in Miami has CFM56 and JT8D-200 capability, and is winding down activities on the latter type. It also has a part-out shop for sourcing USM and other materials. Aerothust can perform 11-12 SVs per month. In addition to the younger types, Aerothrust has also experienced a surge in CFM56-3 SV activity. Aerothrust is a newcomer to the -7B, and started SVs in early 2019. It expects to be a pure CFM56 shop within two years.

Collectively shops will need to increase their capacity by 20-25% to cater for the peak in demand over the next six to nine years. By this time shop visit activity of LEAP-1A/-1B and PW1100G engines will have also increased. AC