Engines have strong residual value retention. Maintenance status is directly linked to maintenance value, which accounts for a portion of a modern engine's market value. Lessors and investors need to be aware of how to monitor and maintain the value of their assets.

The relationship between an engine's value & its maintenance status

Engines are assets with strong residual value retention. This makes them attractive and reliable investments for airlines, lessors and financial institutions. It is well established that engines require good management. This includes ensuring sufficient reserves are paid by lessees or operators which cover future maintenance costs, as well as maintaining values and marketability. This raises the issue of how an engine's value relates to its maintenance status.

Value determinants

Engine market values are determined by several variables, the most obvious of which are market conditions: values naturally decline in a recession and rise again as the industry recovers.

The value of young, popular engines is a function of the manufacturer's list price, and there are two main factors which influence the value relative to this.

"The group of modern, popular engines includes types like the CFM56-5B, CFM56-7B and V2500," says Richard Hough, vice president of technical at Engine Lease Finance. "There are two main elements in an engine's value, and the first of these is engine configuration. This concerns thrust rating. Several engine types now have families of different thrust ratings but actually use the same hardware and only differ in the data entry plug. An example is the CFM56-7B family, which has several thrust ratings. Although the hardware is the same for all family members, the list price for each is different because of the thrust ratings."

Engine investors have to be careful with engine configuration and thrust rating. While a complete engine may have a higher value because of a higher thrust rating, the part-out value also has to be considered. "Although a CFM56-7B27 may have a higher value than a -7B20 or -7B22, they will have the same part-out value because they have the same hardware," explains Tom MacAleavey, senior vice president sales and marketing at Willis Lease Finance. An investor should be aware of this and consider buying lower thrust-rated variants of engine type, especially if part-out is likely.

Another aspect of engine configuration is the quick engine change (QEC) kit. This comprises the assembly of engine accessories, wiring looms, air bleed system, electrical and hydraulic systems, and starter motor. These all need to be mounted on the outside of the engine and are necessary to install it on an aircraft. Installation of the QEC kit on a bare engine takes three to four days. For this reason a bare engine has a weak market value, since engines that are ready for installation are instantly marketable. The status of an engine with respect to the QEC kit is therefore another factor of configuration. Hough estimates the QEC kit can account for up to $1 million difference in an engine's market value.

The second factor influencing an engine's market value is its maintenance status. "Young, popular engines still have a market value when they have zero time remaining to a shop visit and fully expired life limited parts (LLPs)," says Hough.

Brian Robins, head of technical services at the IBA Group explains that a modern engine type still has a carcass value when it has zero maintenance time and its LLPs are fully expired. An older engine type, which is in oversupply, will have a value of almost zero when it has zero maintenance time remaining. "Besides the maintenance status of younger engines only accounting for a portion of total value, the cost of an overhaul and installing new LLPs replenishes a modern and popular engine's value," explains Robins. "The cost of an overhaul for an older type, such as the CF6-50C2 may not completely replenish its value, however. This is because overhauled engines are the only ones in demand, and there will be a high supply of run-out engines. It is often the case with older engines that the cost of a full refurbishment exceeds the value of a zero-timed engine, and so it is uneconomic to put zero-timed engines through a shop visit."

Hough explains that the maintenance value of older engines accounts for up to 100% of their market value.

Investors are interested in the values of modern, popular engines. The market value of a CFM56-7B, for example, will be made up of its carcass value and maintenance value, which should be close to its list price in good market conditions. "The bulk of an engine's base value will be related to its year of manufacture and full maintenance time," says MacAleavey.

In the case of modern engines, maintenance and LLP value may account for only 25-30% of total value. "An example is a CFM56-7B22, which at new will have a value of about $5.4 million," says Hough. "An overhaul, required to get the engine back to zero time maintenance status, accounts for $1.2-1.3 million of this. The LLPs have a list price of $1.5 million, taking total maintenance value to $2.7 million. This is 50% of the new engine's market value. The configuration and carcass value, which includes the QEC kit, accounts for the other 50%. The -7B26 has a higher market value of $6.8 million but the same maintenance cost. Its maintenance value therefore accounts for a smaller percentage of the total value. The value of a fully restored engine will be close to its list price. The configuration value is the portion that gets squeezed. This is because higher thrust-rated engines lose

The maintenance value of an engine relates directly to its maintenance status. The market of a young, popular engine can be fully restored with LLP replacement and a shop visit workscope that zero-times its maintenance condition via an overhaul.

their value faster than lower thrust-rated engines, and so their values get closer together. Over time an engine's market value, for the same level of maintenance status, declines. The point arrives where the cost of maintenance or maintenance value is higher than the market value of a restored engine." The carcass and configuration value is thus reduced to zero, or even less than zero, when an engine goes into market decline. The CF6-50C2, JT8D and JT9D have all reached the point in their life cycle where their market values are less than the cost of fully refurbishing them.

Robins points out that in practice engines rarely get into a state of zero maintenance condition: while an engine may be due for a performance restoration shop visit, its LLPs will still have several thousand engine flight cycles (EFCs) of time remaining. "The only time that engines are completely zero-timed is when an airline goes into bankruptcy and aircraft and engines are repossessed," says Robins. "In this case the engines will be sold in a distressed market and may then only achieve 80% or less of their theoretical carcass value."

MacAleavey points out that the advantage of young engines is their ability to retain residual value. "The maintenance value is accrued over the predicted time on-wing to the overhaul or relevant maintenance, and this rate per engine flight hour (EFH) or EFC is equal to the reserves that should be applied. These collected reserves should then restore the value back to its new, zero-timed value," explains MacAleavey. "The catalogue price of the engine will increase by about 20% over the first 10 years of life, while it will have been depreciated by 30% over the same period. The owner will therefore have made a gain equal to 50% of the original value over this time."

Maintenance status

Given the factors that influence an engine's value investors, lessors and airlines need to closely follow the maintenance status of their engines.

Maintenance status can first be generally assessed by analysing several factors. "Oil consumption, exhaust gas temperature (EGT) margin, borescope inspection and performance data all give an indication of how an engine is performing," explains MacAleavey. The ultimate aim, however, is to make accurate predictions about where an engine is relative to its last and next shop visit and workscope. Aircraft reporting and communication systems (ACARS) have allowed performance data to be passed to ground stations and analysed in real time, which has made the timing of removals for shop visits more accurate. "Although there are a large number of variables that affect the time on-wing between shop visits, accurate predictions of removal intervals can be made. These are required to calculate maintenance reserves. Lessees and operators either have to return an engine in zero-time maintenance condition, or pay for the time on-wing they have used. This has to include the life of LLPs that have been used, taking reasonable stub life into consideration," says MacAleavey. "The problem with paying reserves for time used is predicting the cost of the shop visit that will come later, since shop visit costs vary between different shops for the same workscope. The issue is further complicated because lessees and airlines may already pay different reserves with other engine shops. It is therefore sometimes better to get lessees to overhaul the engine and let them pay their usual reserve rate for the time they have used."

The large number of variables that affect the time on-wing to the next shop visit have to be considered, and then monitored. "The objective is to assess the life since the last shop visit, how the engine is performing and thus what the life until the next shop visit is likely to be," says Robins. "A record of total EFH and EFC since new, EFH and EFC since the last shop visit, and last workscope should first first analysed. The engine's modification status and the remaining lives of its LLPs need to be tracked. The type of parts, whether they are from the original equipment manufacturer (OEM) or parts manufactured approval (PMA) parts, and whether they were new or repaired at the last shop visit influences the removal interval.

"A borescope inspection when the engine changes lessees and at regular intervals gives an insight into how the engine is performing," continues Robins. "A more detailed prediction of time remaining until the next shop visit can be made with the engine's EGT margin and other performance trend monitoring data. This should be considered with the information from its last test cell run."

These factors also influence an engine's maintenance and market value. "Although PMA parts may have the same performance as OEM parts," says Robins. "PMA parts may limit an engine's marketability. Some airlines and regulatory authorities do not allow PMA parts, for example. Overall, however, the objective is to determine where an engine is in its saw-tooth maintenance value curve."

The position of an engine in its saw-tooth maintenance value cycle is itself hard to assess, since there are several maintenance cycles that lay over each other.

The first maintenance cycle relates to the cost of shop visits. Maintenance value obviously declines with time on-wing. The value does not simply decline to the lowest level and then get conveniently raised to full value at each shop visit. This is because the maintenance value is not fully exhausted at the first shop visit in most cases. The first shop visit is usually a performance restoration, with most of the work being incurred on the high pressure turbine (HPT) section. Little work is required on the low pressure turbine (LPT), low pressure compressor (LPC) and fan sections. An engine will therefore have only used a percentage of its maintenance value at the first shop visit. The workscope will then only partially restore the maintenance value it lost during its time on-wing, since work was not performed on many of the engine's modules, and so the maintenance condition has not been restored to a zero-time level.

In the simplest of cases, an engine will then have a second shop visit interval that will be shorter than the first, and the maintenance condition of all modules will be fully used resulting in the need for a full overhaul. The deterioration during this second on-wing interval will start at a value of less than 100%, after the first shop visit and decline to a zero maintenance value. A full overhaul workscope will then take the engine's maintenance status close to zero-timed and therefore close to 100% of original value.

In parallel to this is the life of LLPs - the second maintenance cycle. These have fixed lives in EFCs, and in most cases are 15,000-25,000. A complete set for an engine has a list price in the range of $1.5-2.2 million. The lowest maintenance cost per EFH or EFC is when LLP expiry coincides with the need for an overhaul. LLPs are usually replaced with a few thousand EFC remaining, since this 'stub life' would limit the subsequent on-wing interval to a shorter period than would otherwise be possible. The amortisation of LLPs will then occur on a straight line basis to their expiry, which ideally would coincide with an overhaul shop visit. This amortisation should be over 85-90% of the life of the LLPs.

In many cases, LLP replacement does not come due until a third or fourth shop visit. This may be when a second performance restoration comes due after an overhaul. LLP expiry at a performance restoration is less than ideal, since the engine has to be fully disassembled to allow expired LLPs to be removed and new ones installed.

Overall, the saw-tooth curves of maintenance value with respect to shop visits and LLP amortisation occur semi-independently and combine to form an overall maintenance value profile. Only when an engine has had a full overhaul and full LLP replacement at the same shop visit is its value replenished to near 100% of original maintenance value, but there are few shop visits where this occurs during an engine's operational life.

An engine's maintenance value and cycle needs to be carefully considered. Its rate of deterioration on-wing will be influenced by several operational factors. "These include EFH:EFC ratio and operational environment," says Hough. "Young and popular engines can be relied upon to regain their original market value when they have maintenance to replenish their maintenance lives. Investors should be wary of an engine entering into a phase of market decline when it starts to decrease in popularity. When the numbers of an aircraft type in operation starts to diminish, the fleet of engines supporting that aircraft fleet implodes. The effect is an increasing ratio of spares to installed engines, which weakens their market value. It is possible for the market value of an engine type to reduce to less than the cost of maintenance visits over a relatively short period. A large number of engines being parted out accelerates this effect. One example has been the HPC surge on the PW4000, which caused a problem with the supply of sufficient spares. This was resolved by Pratt & Whitney increasing the supply of manufactured PW4000s, which has had the effect of permanently dumping their values."

Monitoring maintenance status

Once an engine's maintenance status is assessed at the start of a lease, it has to be constantly monitored. The tools for this are trend and performance monitoring, especially with respect to EGT margin. Time on-wing since the last shop visit and its EGT margin erosion rate since then will indicate what is the probable remaining interval. "Time on-wing is also a function of where the engine is in its shop visit maintenance cycle and how the engine is being managed," says Robins.

Scott Badman, vice president technical at TES recommends that engines have a mid-lease inspection to verify that the engine is deteriorating at the originally expected rate. "Trend monitoring is used to predict how long an engine will last on-wing. This his now makes accurate predictions," says Badman. "Established engines have known deterioration curves, and the style of operation determines the deterioration profile the engine will conform to."

Not all engines remain on-wing for as long as predicted, since there are some unplanned removals which occur suddenly. The number of unplanned removals as a percentage of all removals is now smaller than in the past because of the improvements in trend monitoring. "It is now possible to predict the on-wing time for scheduled removals to within 100EFH," says Robins.

End of lease status

Maintenance condition of an engine at lease end is required to compare actual condition and deterioration during the term to be compared with predicted deterioration. Maintenance reserves to compensate for deterioration during the lease are based on predicted deterioration, but lessors require to be fully compensated for loss of maintenance value. A higher degree of deterioration will therefore mean accrued reserves are insufficient to cover subsequent maintenance costs.

Actual maintenance condition is assessed by a test cell or on-wing run of the engine, a borescope inspection, trend monitoring data, log book entries, remaining LLP lives and accumulated EFH and EFC. Leases often state required return conditions, and borescope inspections and test cell runs verify if these conditions have been met. While some leases require engines to be returned in a zero-timed maintenance condition, performing a full overhaul to achieve this at the end of the lease may be uneconomic if the engine can still achieve several thousand EFH on-wing, or if the next shop visit only needs to be a performance restoration. Lessees should therefore negotiate what compensation is reasonable for the predicted amount of maintenance time and value used during the lease. Lessors do, however, usually need to have a short-haul engine with at least 4,000-5,000EFC remaining on-wing time for the engine to be marketable.

Reserves for compensation have two elements. The first of these is LLP amortisation, based on a rate per EFC. The second is for accrued cost of shop visits, based on a rate per EFH. Difficulties can arise when an engine changes lessees between shop visits, since different operating profiles result in different rates of deterioration and so require different reserves to paid. "Reserves from both should combine to cover the cost of the subsequent shop visit, and so have to calculated carefully," says Robins. "A lessor with a harsher operation and higher rate of deterioration will have to pay higher reserves. If the reserves from both lessees fall short of the maintenance cost the lessor may have to pay the difference. Accurate predictions of time on-wing and deterioration are thus desirable, but lessors take a risk with the reserve rates they agree."

Differences in reserves and maintenance cost at the lease end can be settled by compensating lessees or lessors either way. "One method is for an adjustment either way to maintenance cost and reserves paid. Another is for the lessor to give the lessee the cash for maintenance life already used at the start of the lease, and then have the lessee pay for the subsequent shop visit. Another way is for lessors to pro-rate the cost of the shop visit, but this is the less preferred option," says Hough. AC