The 727 is as popular as ever with freight operators. Although some 727-100Fs may soon face retirement, several hundred more -200s are expected to be converted to freighters. With a complex web of ageing issues, Donal James examines what airlines should expect to budget for maintenance.

Budgeting for 727F maintenance

Boeing's 727 – the stalwart of the short-haul passenger fleet – has been recognised for its unique position in the freighter market – providing the majority of medium carrying capacity. Many companies are now looking to invest considerable sums of money to purchase 727Fs and so take full advantage of their freight carrying capacity.

In so doing they are expecting a life of 10–20 years from these aircraft. There are about 1,200 aircraft either still in service, available for service or in long-term storage. The aircraft range between the 727-100s with the Pratt & Whitney (P&W) JT8D-7 and -9 engine, to the -200 with the higher powered engines.

The values of aircraft vary with age, total hours and cycles and maintenance status. With the range of available aircraft still in passenger service, but the number due for retirement being so great, there is a wide range of aircraft for the freighter operator to choose from.

This analysis is a guide to assist the planning and engineering departments of operators and maintenance companies in setting up a maintenance plan and assessing the actual maintenance cost for the aircraft. This guide provides a maintenance plan with costings that can be factored into the overall aircraft or fleet operating costs.

Both the 727-100 and -200 can be purchased and modified by use of various supplemental type certificates (STCs) into freighters, and both have their place in the market. Many companies have taken the modifications further to improve aircraft performance and cargo capacity. The requirement for Stage 3 hushkits and noise compliance has produced a plethora of new and modified engine combinations, along with modifications to the flaps and wing tips, all of which have assisted in noise reduction. There is the additional benefit of increased performance and reduced fuel consumption. This is notable with the Duganair system, which saves 4–6% fuel compared to other modifications, depending on sector length. The avionics suite has also been modified on many aircraft to improve reliability.

With a range of aircraft variations, many of which are operator specific, this article will concentrate on the baseline aircraft itself. Operators flying individually modified aircraft will therefore be able to filter relevant information for themselves. These

Total maintenance costs for the 727F are in the region of $900 per FH for an aircraft achieving a utilisation of about 1,400FH per year. About one-third is accounted for by engine reserves, another third for line maintenance and the remainder for B–D checks.

SUMMARY OF 727F LINE MAINTENANCE REQUIREMENTS

Maintenance task	Maintenance	Manhours (routine)	Materials ($)	Spares ($/FH)	Defect rectification (MH/FH)
Transit check		0.5			
Daily check		1.5	10		
Weekly check	7 days	2.5	80		
A check	155FH	18 routine 36 non-routine	250		36
Avionics				48	0.1
Airframe systems				15	0.1
Engine systems				10	0.1
Wheels	150FC			36	
Brakes	450FC			52	
Total/FH		**0.83**	**21.7**	**160.5**	**0.53MH/FH**

SUMMARY OF B CHECK MAINTENANCE FOR 727F

B check maintenance	Manhours	Defect rectification (MH)	Consumable materials ($)	Rotable spares ($)
B check-routine				
Airframe	70	105	750	
Engine & APU	20	30	500	
Avionics	10	5	150	
B check inspection				
Airframe	25	50	1,200	25,000
Engine & APU	20	30	750	10,000
Avionics	15	10	250	45,000
SBs & ADs	25			
B check totals	**85**	**230**	**3,600**	**80,000**

operators will have the data on the modified systems that will allow the calculations to be completed.

Airframe maintenance

The maintenance planning document (MPD) published by Boeing was developed to provide a minimum guide for aircraft maintenance, its systems and accessories. It provides the backbone for all the various maintenance organisations and aircraft operators to use for the production of maintenance schedules or programmes.

The 727's MPD has not been revised since 1982. Any major changes in maintenance requirements are being dealt with now by separate documents, for example the Corrosion Prevention and Control Program (CPCP), the Significant Structural Inspection Document (SSID) and the Ageing Aircraft Programme.

These documents are supported by various Airworthiness Directives (ADs) issued by the Federal Aviation Administration (FAA). The operators are therefore charged by their regulatory authorities to update the maintenance schedule to include all the current requirements. It is down to the operator's planning engineers to create a workable programme that will group and plan tasks to prevent double access requirements and reduce labour man-hours (MH) and downtime.

Every company will have differences in the maintenance schedule they have produced for their fleets and this will produce variations in maintenance costs. There are other variables to consider, and where possible this analysis indicates the minimum and maximum figures available.

The airframe systems used in these second generation aircraft are more sophisticated than those of first-generation aircraft. The use of two independent hydraulic systems with an additional standby system, allows the use of hydraulic powered flying controls, but incorporates manual redundancy. Maintenance of the flight control systems is therefore made more complicated than in either the first-generation aircraft or the present-day fly by wire systems.

The air-conditioning and pressurisation system is reliable and cost-effective to maintain. The electrical power systems still use the first-generation paralleled bus system, but the more modern electronic control system has improved reliability. The removal of the passenger cabin items and conversion to freighter reduces the costly (in terms of MH and material) task of maintaining the passenger cabin. The airframe itself suffers from the typical problems of corrosion and fatigue. Adequate maintenance will prevent the airframe deteriorating to an irreparable condition.

The cost of maintenance will grow in proportion with the age of the airframe. Many operators and finance departments have a budgeting problem with maintaining relatively old aircraft. They often feel the expenditure of possibly 20–30% of the capital acquisition cost of an aircraft in a heavy maintenance visit (HMV) does not 'stack up' in accounting terms. However, justification for maintenance expenditure will be understood if such costs are factored against income generation, rather than capital acquisition costs.

Most operators now seem to use on-condition maintenance for the majority of the rotable components. On-condition maintenance is now more cost-effective because of improved component reliability.

Powerplant maintenance

The JT8D series engines that power the 727 are well-established and mature. It is therefore relatively easy to apply actual costs for the overhaul, restoration and repair of the core unit and its accessories. The provision of spares has a wide-ranging impact on the final cost of the actual refurbishment of the engine.

Over the lifespan of the engine, the number of flight hours (FH) and flight cycles (FC) compared to the use of a particular quality of consumable and rotable spares will be analysed by an operator's engine reliability reports. Hence, the quality of spare parts used will have a direct baring on the mean time between removal (MTBR).

The analysis of engine removal data against reliability indicates that low

MTBR figures are often due to single unpredictable component failures. By contrast, engines achieving high MTBR figures are removed either because of reduced exhaust gas temperature (EGT) margins, due to general wear and tear, or life expiry of rotating components that can be predicted with accuracy using engine condition monitoring (ECM) and life limited parts (LLPs) monitoring.

The JT8D-200 series engine fitted to a small number of re-engined aircraft brings improved field and payload performance. The overhaul and restoration costs are higher than with the earlier JT8D engine, which is an acceptable penalty for the newer technology and improved performance.

Spares requirement

The issue of spares used on the aircraft is more difficult to predict than consumption of engine parts. There is a large market of spares available for purchase, with a variety of paperwork claiming serviceability ranging from 'tested' to 'overhauled'.

The price range for these items is unpredictable. An overhauled unit can cost up to 100% more than a repaired item, but the use of off-the-shelf units does not guarantee any greater reliability or better MTBR figures.

In an ideal world the operator would have access to his own spares pool, and so carry out in-house repair and overhaul. This would result in the operator benefiting, in the long-term, from investment in quality maintenance. This might be more expensive in the short-term, since it may appear that there are cheaper units on the open market. Experience has generally shown that an airline maintaining its own core units and controlling restoration through the various repair organisations will improve the reliability of parts.

There are companies that undertake to maintain an operator's entire stock of units, some being more specialised that others. Using these companies can bring major long-term cost savings and reliability improvements.

The alternative method of improving reliability and reducing cost is through the re-engineering of the system and replacement of the components with new state-of-the-art equipment and systems. There are numerous STCs available in the market for the fitting and replacement of new and upgraded units and systems.

Several major 727 operators have elected completely to re-engineer the avionics and flight systems suite in the aircraft while carrying out a cargo conversion. These operators have reaped the benefit of improved reliability and reduced maintenance cost.

As a rule of thumb, the overhaul of units for airframe systems and avionics will account for 50–70% of the cost of direct purchase on the open market.

Line maintenance

Line maintenance for the 727 consists of all checks up to and including A checks (or equivalent) being carried out by line personnel. This assumes use of line access equipment and technical or overnight stops to complete the scheduled tasks.

Mechanics are required to carry out the non-routine work generated by the flightdeck crew technical log entries, the airline maintenance planning department, non-routine maintenance and inspections and the correction of deferred defects. The line environment should be adequately staffed to allow all inbound defects to be 'worked', so that they are either rectified or have the spares ordered and defect deferred. There should also be enough manpower to allow the routine inspections to be adequately acted on.

The cost of line maintenance is distorted by the intermittent use of engineering staff on aircraft turn-rounds and layovers/night stops. This necessitates having additional staff on

SUMMARY OF 727F C CHECK MAINTENANCE

Maintenance item	Manhours	Defect rectification Manhours	Rotable spares ($)	Consumable materials ($)
C check routine inspection			125,000	19,850
Airframe systems	120	240		
Engine & APU	85	170		
Avionics	60	120		
Structural	250	500		
C check routine work				
Airframe systems	160	80		
Engine & APU	50	25		
Avionics	25	25		
ADs	300	300		
CPCP	750	750		
SSID	130	130		
Average totals	**1,600**	**2,340**	**125,000**	**19,850**

SUMMARY OF 727F D CHECK MAINTENANCE

Maintenance item	Manhours	Defect rectification manhours	Rotable spares ($)	Consumable materials ($)
D check routine inspection work	7,500	15,000	180,000	45,000
ADS, SSIDs, CPCO	2,150	3,950	19,750	

duty to take care of the peak time, with consequent overstaffing at other times.

The table (*see page 48*) summarises the average MH requirements for a 727, but does not take into account the cost of supporting a line operation. These costs assume an average utilisation of 4FH per day and an average FC of 2FH.

B Checks

The B check requirement is a maintenance interval of 450–600FH. An aircraft with a utilisation of 4FH per day will therefore achieve an average 112–150 days between B check routine work and inspections. A limited amount of CPCP and structural inspection work will be carried out during these inspections. Other modifications may also be necessary. An average interval of 525FH and 130 days is assumed to be achieved between checks.

C checks & HMVs

The C check is now usually divided into equalised checks, incorporating the D check or HMV. Some operators elect to continue using a standalone D check.

C check intervals have been extended by roughly twice the MPD recommended interval of 1,600FH. The world fleet average interval is now approximately 3,150FH. The majority of aircraft currently had the structural modification programme applied and are into the first and second repeats of the CPCP.

Many fleets now control the rotable components by an on-condition, condition-monitored or soft time inspection interval, rather than a hard time maintenance schedule.

The cost of having a hard time programme for components can be considered excessive, when compared to the perceived benefits. The aircraft reliability data from the strip and overhaul reports can be analysed to assess the economic viability of continuing the hard time component maintenance schedule.

There will be many cases in which an assessment can be made allowing escalation in hard time intervals, or removal from the hard time programme and applying an on-condition programme with an *in situ* inspection requirement. The application of MSG3 principles to this task will have a definite economic benefit.

The D check interval in the MPD is recommended at 16,000FH, or every 10 C checks. The world fleet D check interval average is now 20,500FH (a 25% escalation of the MPD).

The 20-year and 60,000FH ageing aircraft programme is normally incorporated into the D check or HMV. Another option is to stage the incorporation of the ageing modifications into the C checks, leading up to the 20-year or 60,000FH limitation. With planning this can be achieved without disruption to the C check. There may be benefits from the MH saved, due to joint access being gained through inspection requirements from the CPCP and SSID tasks.

The ratio of MH used in routine inspections, against MH required to rectify defects found during inspections is dependent on 1) the age of the aircraft, 2) area of operations, and 3) previous service history.

But note the following:

1) The cost of inspection and rectification due to ADs is included, but as this is variable, a typical budget of 300MH can be factored. Hence, while planning the C check an accurate figure can be budgeted for.

(2) The cost of rotable spares is due to unserviceable components found during the routine inspection. The components removed due to hard life expiry are not factored in. However, it is necessary plan for hard time component removals when the component call-off list is determined in the C check planning stage.

(3) CPCP and SSID costs are averaged. Again, this actual cost depends on how the programme is implemented. A ratio of 1 : 1 for rectification can be planned for, depending on experience with the fleet and the overall condition of the actual aircraft.

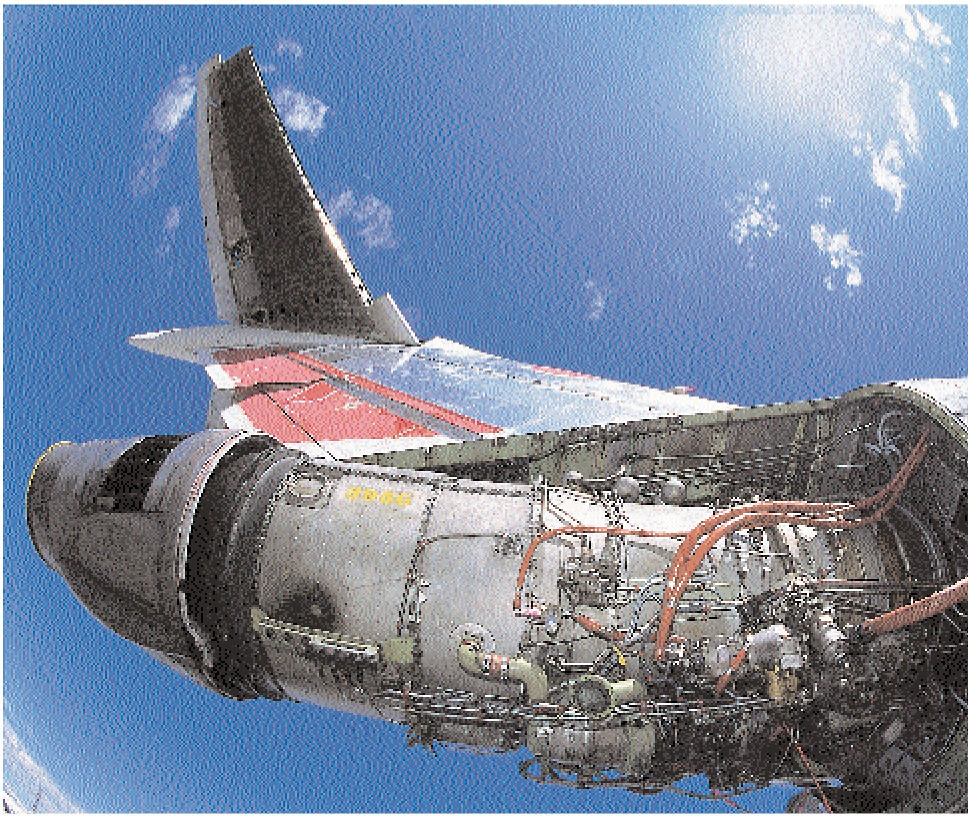
(Total MH required to complete D checks will vary depending on aircraft structural condition. Therefore MH requirements can vary between 10,000 and 25,000.)

Post storage restoration

An aircraft that is to be converted into a freighter after long-term storage will normally have a D check carried out as part of the freighter conversion process.

The ageing aircraft modification element of the check will depend on the age and aircraft line number.

The 727's maintenance costs are complicated by a wide variation in utilisation, ageing aircraft and CPCP requirements, man-hour consumption and age and cost of components.



APU HSI & overhaul

Auxiliary power unit (APU) maintenance is divided into *in situ* maintenance carried during normal B and C checks and shop visits every 18–24 months for an APU hot section inspection (HSI). This equates to about 2,500APU start cycles. Many operators now exchange the combustion chamber and fuel nozzle assembly during the B check. This ensures start performance is maintained and prevents fuel burner streaking that will damage the hot section components.

The HSI will cost $7,500–10,000, and overhaul will be $20,000–55,000.

Landing gear

The 727's landing gear has a overhaul interval average of 18,000FC or 8–10 years (CPCP). The low average FH utilisation and the CPCP gear overhaul interval of the 727F results in a landing gear overhaul becoming due every 15,000FH.

The cost of exchanging a set of gears will be in the region of $130,000–180,000 (including exchange and rectification costs). This does not include the cost of upgrading lightweight gear to heavyweight gear.

Summary and reserves

In conclusion, the ever-popular 727F has proved its worth since its introduction in the 1960s. The 727 will continue into the new century as a economic and effective freighter aircraft.

The data in this article is summarised (*see table, this page*) to produce the maintenance reserves required to cover all maintenance elements. Individual operators should be able to adapt this information to produce an accurate assessment of their own maintenance requirements and therefore budget accurately for their requirements.

SUMMARY OF AGEING AIRCRAFT WORK FOR 727

Ageing aircraft modification due at 20 years

Service Bulletin	Line number affected	Manhours required
SB55-62	001-641	1,200
SB55-69	001-874	800
SB55-73	001-889	50
SB53-85	001-540	1,400
SB53-128	001-765	1,400
SB53-144	(-200 Series) ← 1,217	800
SB53-159	(-200 Series) 433-1,216	1,400

Manhours required to accomplish ageing aircraft service bulletins for aircraft exceeding 60,000FC

Line number	0	150	500	600	650	750	800	1,100	1,250	1,500	1,700
Man-hours	21,000	19,000	18,500	16,000	15,000	13,000	7,500	7,000	3,000	2,500	2,250

D check/structural inspection (SI) non-routine to routine man-hours by age of aircraft

Age in years	5	10	155	20	25
Non-routine : routine ratio	1.0:1	1.2:1	1.55:1	2.2:1	2.7:1

Manhours required for complete CPCP implementation	
Independent of C or D check	5,460
Combined with average C check	5,525
Combined with D check	2,600

SUMMARY OF 727F FH MAINTENANCE RESERVES

Maintenance item	Manhours Min	Manhours Max	FH interval Min	FH interval Max	Spares Rotable $	Spares Consumables $	Cost/FH MH = $50
Transit	0.25	0.50	2	n/a			
Daily	1.5	2.0	1	6			
A check	40	60	100	160			
Total 'line'							250
B check	245	375	450	600	80,000	3,600	189
C check	Average of 3,940		Average of 3,150		125,000	19,850	109
D check	Average of 17,500		Average of 20,500		180,000	45,000	54
Reserve for APU							12
Reserve for landing gear							10
Reserve for three engines							273
Total reserves/FH							897

727 freighter conversions

Hamilton Aviation and partners, Timco and Eagle One, have now received their STC approval for the modification and conversion of the 727 to a full freighter aircraft, taking advantage of the maximum allowable loading available.

The new Hamilton Aviation conversion STC covers the installation of a full freight upper deck door, strengthening of the floor structure, fitting of a 9G crash barrier and installation of a Class E compartment and full freight system, including side restraints.

The STC complies with all the requirements of the ADs currently in force on the 727F. These ADs curtail payload and aircraft cruising. Boeing engineers have viewed the package and feel that it meets with their original equipment manufacturer standards.

Hamilton Aviation has developed the first FAA approved finite element model to support its STC. From this model a complete SSID document has been developed to cover the modification. The data package developed for the Hamilton conversion can be adapted for previously modified aircraft. Using this information Hamilton will be able to offer modifications and data to support the existing structure and develop repairs to improve the failsafe characteristics.

Hamilton Aviation produced the first two aircraft as part of the STC acceptance and has six more aircraft currently in work. There are firm orders for 22 aircraft and 45 options have been taken.

Hamilton Aviation, Timco and Eagle One, plan between them to have 12 aircraft in work at any one time. The intention is for an aircraft to have a modification turnaround time of 90 (100 including painting). They are expecting to deliver four aircraft every month. Full maintenance availability will also allow C and D checks to be completed concurrently. The turnaround time will be reduced as production builds up to full capacity.

There are currently 700–800 candidate aircraft in the world fleet. Hamilton Aviation, Timco and Eagle One hope to complete 120 aircraft over the next three years and 200–400 over the next eight years. AC