The demand for base maintenance hangar capacity is determined by the fleet size of each aircraft type and the maintenance schedule they operate under. Base maintenance checks are forecast to exceed 12,000 in 2001. The capacity needed to meet this demand is a quarter of that available.

The abundance of base maintenance hangar capacity

The traditional practice of all major airlines having their own maintenance facilities in the past led to an oversupply of maintenance capacity compared to the total required. Once a global maintenance market had been established this oversupply led to falling man-hour (MH) rates. Few new major facilities have been established since the mid 1990s, while the global fleet, and demand for maintenance, has continued to grow. Could fleet growth eventually lead to demand for hangar capacity equalling supply, and so cause MH rates to rise?

This survey analyses the estimated annual requirement for C, 4C and 8C/D airframe checks, or 'base' maintenance, for all types from the F.28 up to the 747. This is split into the global regions of North America, Central and South America, Europe and the Commonwealth of Independent States (CIS), Israel, the Middle East, Africa, Asia and the Asia Pacific, and Australasia. This requirement is then converted to the number of narrowbody and widebody bays theoretically required in each of these regions to satisfy this demand.

This demand is in turn compared to the number of narrowbody and widebody bays dedicated to base maintenance in each global region.

Hangar capacity demand

The majority of aircraft types now operate on an A, C, 4C and 8C check system, with only a small number like the 747-200 still including D checks in their schedules. The 4C check is an intermediate structural check, while the 8C is a full structural check, and takes the place of a D check.

Most airlines which have their own facilities for heavy maintenance, sometimes referred to as 'base' maintenance, have separate hangars for C and D checks. The majority of these carriers with these facilities are the larger airlines, which can justify the overhead and guarantee enough work to utilise the hangar. Some of these airlines sell excess base maintenance capacity on a third-party basis to smaller airlines.

Other capacity for base maintenance is supplied by independent providers. Few independents offer capacity for line checks.

Maintenance programmes

Only the 747-100/-200/-300, DC-10 and L-1011 have C and D checks. The majority of other types have a C, 4C and 8C check maintenance programme.

C check intervals for most narrowbodies are 3,000-4,000FH and 15 months. The A320, for example, has a longer interval than the 737 or MD-80. These C check intervals are equal to the time between about 7-10 A checks.

C check intervals for some widebodies are longer than for narrowbodies; in the region of 4,000-5,000FH. Because of the higher annual utilisations achieved by widebodies, calendar intervals between C checks are similar at 15-18 months.

The intervals of 4C checks are simply a multiple of four of the basic C check interval. D checks, or 8C checks, for most types are performed at a multiple of eight of the C check. The 737-200 and -300/-400/-500 have a 7C check as the heavy structural check.

The DC-10 and 747 have D check intervals of about 20,000FH and 22,000FH.

The A300/310/330/340 have a similar system to the A320, where intermediate and full structural checks are performed about once every five and 10 years.

The range of C, 4C and 8C/D check intervals for each aircraft type is provided by *Avsoft*, and summarised *(see table, page 23)*.

Fleet maturity

These intervals mean that as a new type is introduced into service there is a lag period of up to 10 years before the first major structural checks are performed. There is therefore a delay of 8-10 years until the fleet matures, when the number of structural checks carried out annually starts to increase. For example, the A320 entered service in 1989 and the first 8C checks were not performed until 1998. Air France Industries has completed 50 8C checks for A320s, while other facilities have yet to perform their first.

This time lag to maintenance maturity is repeated for all types. It is also exacerbated by the increasing intervals between 8C or D checks of modern aircraft types. The implications of this are that an increase in demand for hangar capacity will follow 8-10 years after delivery of new types like the A330/340, A320, 737NG and 777. The first 4C and 8C checks for these types have already been performed, but it will be several years before the number made each year reaches its peak. The increasing number of 777, A330/340, 737NG and A320 deliveries should therefore trigger an increased demand for hangar capacity later this decade.

This is paralleled, however, by retirements of DC-10s, 747s, DC-9s, 727s and DC-8s. These aircraft have longer elapsed downtimes for C and D checks, and so require more hangar capacity than their younger counterparts. Older types have shorter intervals between checks, which adds to their higher capacity requirements. This effect is offset by the growing global fleet, which will increase demand for hangar capacity. Because of the lag effect of maintenance maturity, demand for hangar capacity will therefore increase at a faster rate after about 2005.

Check downtimes

There are several determinants of hangar capacity requirements to complete all C and D checks for the global fleet of jetliners. One important factor is elapsed downtime required to complete checks.

Elapsed downtimes are affected by the MH input required, the labour force employed and MH available each day and week and the number of daily shifts the facility operates.

Elapsed times for the same aircraft vary between operators, because of differences in maintenance schedules and check workscopes. Downtimes can also be extended by delays or additions to checks.

A 747-200/-300 D check, for example, should be completed in six or seven weeks, but this is often extended by two weeks because of delays. A downtime of 65 days is often required.

This implies a widebody bay with 747 capacity could perform six 747 D checks nose-to-tail in a year. This just considers the theoretical capacity of each hangar bay on the basis of downtime to complete a check. There are also several other issues which determine a hangar bay and facility's annual C and D check capacity. The most important of these are available tooling, labour, aircraft type capabilities and aircraft operating schedules.

A D or 8C check for other widebody types will not take as long as for a 747. A heavy visit for a MD-11 takes about 30 days in many cases, and so a hangar bay would have a theoretical capacity of 12 D checks a year.

These calculations can be applied to all aircraft types for their C, 4C and 8C/D checks across the global fleet, and so determine the number of hangar bays theoretically required.

The actual ability for a facility to use each of its bays dedicated to C and D checks utilising all the time during the year is modified by its labour resources and other factors. The implications of this are that the global supply of C and D check capacity is less than indicated by just the number of base maintenance hangar bays.

HEAVY MAINTENANCE PROGRAMMES AND TYPICAL CHECK INTERVALS

Aircraft type	C check	4C check	8C or D check
BAE 146/Avro RJ	12 mths	48 mths	96 mths
Fokker 100	3,000 FH	12,000 FH	24,000 FH
DC-8	12 mths, 3,600 FH		
DC-9	2,500 FH	10,000 FH	20,000 FH
MD-80/90	15 mths, 3,250 FH	15,000 FC	30,000 FC
707/720	12 mths, 3,600 FH		N/A
727	3,150 FH		20,500 FH
737-200	3,000 FH		20,000 FH (C7)
737-300/-400/-500	3,200 FH		22,400 FH
737-600/-700/-800/-900	15 mths	60 mths	120 mths
757	15 mths	60 mths	120 mths
A320 family	15 mths, 4,000 FH	5 years, 16,000 FH	10 years, 32,000 FH
DC-10-MSG 2	17 mths, 5,000 FH		20,000 FH
DC-10-MSG 3	5,200 FH	10,000 FH	N/A
MD-11	15 mths	60 mths	120 mths
747-100/-200/-300	5,000 FH		22,000 FH
747-400	15 mths	60 mths	120 mths
767	18 mths, 6,000 FH, 3,000 FC	72 mths, 24,000 FH, 12,000 FC	
777	12 mths	48 mths	96 mths
A300B2/4	15 mths	60 mths	120 mths
A310	15 mths	60 mths	120 mths
A300-600	15 mths	60 mths	120 mths
A330/340	15 mths	60 mths	120 mths
L-1011	3,500 FH		20,000 FH

Source: AvSoft

Labour capacity

While a hangar may be able to accommodate a certain number of C or D checks each year on the basis of elapsed days to complete a maintenance visit, this number of theoretical checks is likely to be reduced by labour capacity available.

Facilities will only employ enough staff to complete the checks it knows it is likely to perform in a year, rather than the amount required if each bay was constantly filled with C or D checks nose-to-tail throughout the year. The amount of labour employed by an airline is also closely geared to meeting the requirements of its own fleet.

A small national airline which performs its own heavy maintenance may, for example, have five DC-10s in its fleet. Each D check may take about five weeks and consume in the region of 40,000MH. Labour consumption would then be equal to about 8,000MH per week. With overtime an employee may contribute about 55 hours per week, and so about 150 employees would be needed for heavy maintenance to perform this check.

A D check will be performed on each aircraft once every five years, and so only one D check would then be performed by the airline annually.

Each aircraft would also have a C check in the year and consume in the region of 7,000MH, over a period of 7-8 days. The 7,000MH used during the week means, again, about 150 employees providing 55MH including overtime would be required.

There would be five C checks during the year, consuming a total of 35,000MH. Total hangar capacity required for heavy DC-10 maintenance would be about 10 weeks, and use 75,000MH during this short period.

Although the hangar bay would only be used for 20% of the year, this does not mean the airline would be able to use the hangar for the remaining 80% of the year. This would first require a guaranteed flow of work at the same level. There would have to enough checks to consume the remaining labour. At a less intensive work rate an employee contributes about 2,250MH a year. This means a staff of about 180 mechanics would be needed for C and D checks for the airline's five DC-10s alone, plus the third-party work required to constantly

European airline and independent facilities provide an excess of capacity in relation to demand for hangar space compared to the number of checks generated by the fleet in each global region.

fill the hangar to keep the employees occupied. These 180 staff would provide about 300,000MH each year. Additional personnel would also be required for other aircraft in the fleet and line maintenance. This number of employees is not kept by many airlines with fleets of this size, irrespective of their hangar bay capacities.

An airline in this position is unlikely to sell enough third-party maintenance to constantly fill hangars dedicated to heavy maintenance. The labour employed for all maintenance, including line checks and other aircraft types, would be planned so that peak labour requirements for the widebody C and D checks, and the carrier's narrowbody D checks, were accounted for. These peaks would have to be catered for by large amounts of overtime for employees over short periods.

Additional manpower could be supplied for a few weeks at a time from mechanics working on line maintenance and smaller aircraft types. These short peaks of labour would be followed by extensive periods of less busy work schedules in the heavy maintenance facilities. It is for this reason that many small airlines only perform line maintenance, and sub-contract heavy checks.

The number of employees kept at a facility for base maintenance puts a cap on the number of C and D checks that can be performed each year. This is lower than than the number of checks that could be performed if average check downtime were the only factor in limiting hangar capacity.

Seasonality of operation

One factor preventing constant use of hangar bays is seasonality of aircraft operations. This can be partially balanced out if checks from aircraft used in different styles of operation can be planned.

Passenger and holiday charter carriers have peak operating periods between spring and summer, while freight carriers are busiest between September and the end of the year. These result in different times of the year when they are busiest with heavy maintenance.

It is nevertheless impossible for most facilities to get a steady flow of work throughout the year. The summer peaks at different ends of the year in the northern and southern hemispheres can be partially offset by a few facilities with heavy capabilities for the largest aircraft; improving hangar utilisation.

Troughs of maintenance activity in the summer are still inevitable, but can be exploited by having a large number of staff holidays.

Utilisation gaps

While each bay has a theoretical annual capacity on the basis of downtimes to complete checks, a string of nose-to-tail checks scheduled constantly through the year will be impossible. This is due to delays to checks, preparation and clearing of hangars before and after checks, and the inability to schedule work at ideal times.

This means 70% or less of the theoretical number of checks that could possibly be scheduled in each bay will actually ever get completed in a year. These problems can be offset by facilities using smaller work packages with short downtimes to fill some of the gaps between larger checks. Examples of these small packages are A and B checks, casualty work and modifications.

Facility sub-division

In many cases hangars for line maintenance are clearly located at different sites for base maintenance. Lufthansa Technik, for example, has a comprehensive hangar facility at Frankfurt for line maintenance, but uses its Hamburg and Berlin facilities for base maintenance.

In other cases hangars are used for a combination of A, C and D checks. One example, is Air France Industries' facility at Paris Charles De Gaulle airport.

This extensive dual use of facilities by airlines and independent maintenance providers makes it hard to decipher how much capacity there is for base maintenance. This use of base maintenance hangar bays for some A checks then means global demand and hangar capacity for line, A and B checks has to be considered.

Redundant capacity

The change in attitudes of airline managements in the past 15 years to essential and non-essential activities has seen several major airline maintenance facilities suffer a reduction in their workloads.

While most airlines regard it a false economy to sub-contract line maintenance, the global or even regional differences in labour rates and small fleet sizes means it has become economic for some airlines to outsource base maintenance. Austrian Airlines, for example, has an extensive facility at Vienna and continues with line maintenance. It made the decision, however, to completely sub-contract its base maintenance to facilities in other parts of Europe with lower labour costs. This has left Austrian's maintenance capacity underutilised. Because the workforce is now redundant, the airline is unlikely ever to be able to re-acquire such a capability. The implications of this are that the number of bays available for base maintenance is less than those in existence.

ANNUAL NUMBER OF FORECAST C, 4C & 8C/D CHECKS FOR 2001

	North America	C/S America	Europe/ CIS	Israel	Middle East	Africa	China	Asia Pacific	Australasia	TOTAL
Narrowbodies										
C checks	2,823	352	1,735	15	62	120	267	289	138	5,801
4C checks	825	83	413	10	21	30	62	82	27	1,553
8C checks	544	31	193	1	3	17	36	22	18	865
Total checks	4,192	466	2,341	26	86	167	365	393	183	8,219
Widebodies										
C checks	1,099	99	629	8	120	83	138	606	107	2,889
4C checks	328	24	157	2	27	35	34	164	23	794
8C checks	187	18	80	1	8	6	17	69	14	400
Total checks	1,614	141	866	11	155	124	189	839	144	4,083

Source: AvSoft

THEORETICAL NUMBER OF HANGAR BAYS TO COMPLETE FORECAST C, 4C & 8C/D CHECKS FOR 2001

	North America	C/S America	Europe/ CIS	Israel	Middle East	Africa	China	Asia Pacific	Australasia	TOTAL
Narrowbodies										
C checks	65	8	37	1	1	3	6	6	3	129
4C checks	17	2	9	0	0	1	1	2	1	33
8C checks	57	3	20	0	0	2	4	2	2	91
Total Bays	140	13	66	1	2	5	11	10	5	253
Widebodies										
C checks	24	2	15	0	3	2	3	15	2	67
4C checks	9	1	4	0	1	1	1	4	1	22
8C checks	25	2	11	0	1	1	2	9	2	54
Total Bays	58	5	30	0	5	4	7	29	5	142

Assessing the capacity supplied by hangars available is made difficult by some having several combinations of the number of narrowbodies and widebodies they can accommodate. The issue is further complicated by some facilities using bays for both line and base maintenance.

Total capacity demand

Total annual demand for base maintenance capacity is determined by the total fleet of each type, the aircraft's maintenance schedule as operated by each carrier and the downtime in elapsed days to complete the check.

For example, capacity required for 737 C and 7C checks in the US is first determined by estimating the number of C and 7C checks that will be performed in a year. It is expected that about 800 C checks and 200 7C checks will be performed for the 737 in 2001 for the North American fleet. This estimate is made by *Avsoft*.

These estimates are made on the basis of the maintenance schedule for each aircraft used at each operator. These schedules and check intervals are then compared against the age of each aircraft, total utilisation since delivery and in the past 12 months. This is done for each aircraft in the fleet, and the number of C and 7C checks is then forecast for the year. This is repeated for all aircraft types for all airlines.

This analysis examines capacity requirements for C, 4C and 8C/D checks for all passenger jet aircraft of the F.28's size and up to the 747. The fleets of each type are sub-divided into the global regions used in this analysis.

This process of estimating the number of checks performed is complicated by differing types of maintenance schedule between types.

Although downtimes in elapsed days vary between airlines and individual aircraft, a generic average will provide a strong indication of capacity required. The A320's schedule, for example, uses equalised C checks. Downtimes in elapsed days to complete these C checks is 4-9 days, but average seven days. A similar downtime is required for 737-300/-400/-500 C checks.

The total number of C, 4C, 8C/D checks forecast for each aircraft type by *Avsoft* are summarised by global region *(see table, page 26)*. This number of forecast checks has to be first considered against their collective downtimes and so the theoretical number of hangar bays required to complete them.

Unsurprisingly, North America and Europe generate the highest number of checks. Narrowbodies in these two regions alone are forecast to generate about 2,800 and 1,700 C checks respectively. This is accompanied by about 1,100 and 630 widebody C checks in North America and Europe *(see table, page 26)*.

Central and South America, China and the Asia Pacific also generate large volumes of heavy airframe checks.

Because of longer intervals, forecast numbers of 4C and 8C/D checks are less than C checks. Total narrowbody and widebody 4C checks forecast for 2001 are 2,347 *(see table, page 26)*. The largest markets are again North America and Europe. North America is forecast to generate 825 narrowbody and 328 4C checks. Europe should require 413 narrowbody and 157 4C checks. Total global 4C checks are 1,553 for narrowbodies and 794 for widebodies *(see table, page 26)*.

Total global generation of 8C/D checks is forecast to be 865 for narrowbodies and 400 for widebodies. North America and Europe account for more than half of these heavy checks, while Asia and Asia Pacific account for the third largest portion.

Total number of global narrowbody C, 4C and 8C/D checks is 8,219. The number for widebodies is about half, at 4,083 *(see table, page 26)*.

Theoretical capacity

The estimated number of C checks that have to be completed for the North American 737 fleet is about 800 for 2001. A simple calculation, which allows a 10% additional time to the check downtime as a gap between subsequent aircraft means a single hangar bay could theoretically cope with 45 737 C checks in a year. The annual estimated demand for 800 737 C checks could then be accommodated in 18 hangar bays in North America, if each one constantly performed C checks nose-to-tail.

On the same basis, the North American 737 fleet is estimated to require almost 200 7C checks. An average downtime of 40 days plus up to another five for delays and gaps between scheduled checks, means a single bay could cope with eight 737 7C checks in a year. This implies 25 hangar bays would be required to accommodate all 737 7C checks in a year in North America. This then means a theoretical total of about 45 hangar bays are required for all base maintenance for the North American 737 fleet.

The theoretical number of narrowbody and widebody bays to complete these C, 4C, 8C/D checks are summarised *(see table, page 26)*. For narrowbodies this is 129 bays for C checks, 33 bays for 4C checks and 91 bays for 8C/D checks. This totals 253 narrowbody bays globally for all base maintenance on narrowbodies. About half of these are required in North America, home to the largest narrowbody fleet, and a quarter in Europe *(see table, page 26)*.

For widebodies a total of about 142 bays are required for base maintenance. About 40% are required in North America, while Europe and Asia and the Asia Pacific each account for another 20% each *(see table, page 26)*.

This theoretical number of bays is escalated in reality by the factors already described; limitations placed by tooling, labour employed and seasonality of aircraft operations. These factors, plus

US major carriers have large amounts of capacity which they use for their own fleets. This contributes to the excess of hangar capacity in relation to demand for space.

the inability to schedule checks in an ideal order one behind the other means the number of checks a hangar bay could cope with in reality can be only half of its theoretical annual capacity based on downtimes alone.

If a hangar bay is only able to use 60% of its theoretical capacity based on downtime, then more than 400 narrowbody bays dedicated to base maintenance would be needed, and about 240 for widebodies.

The actual capacity of each hangar bay will depend on the amount of work it is likely to be able to get for a year. A large carrier like American or Delta, with large fleets, will have a constant stream of C and D checks for the same aircraft. They will thus be able to provide labour accordingly and use a high percentage of their hangar capacity based on check downtimes.

Total hangar bay requirements cannot only be regarded on a global basis. Apart from a portion of heavy checks for 747s and other large widebodies, most aircraft have their C, 4C and 8C/D checks performed in the same global region as their base of operations. Regional hangar bay capacities and availability therefore have to match regional requirements. A shortage of narrowbody capacity in Europe and surplus in North America is unlikely to incentivise European airlines to send narrowbodies for 4C and 8C/D checks to North American facilities. It will, however, increase MH rates in Europe.

Available capacity

Establishing how much capacity there is for base maintenance is made difficult by several factors. The first is that some hangars are used for a combination of line and base maintenance. The second is that some hangars have both widebody and narrowbody bays. Both can be accommodated at the same time, but the combinations of how many of each type vary. Another difficulty in estimating bay capacity is that some bays can only be used for small checks over short periods, because they can physically block aircraft in other bays undergoing heavier checks.

One other problem is that major airlines do not fully disclose their capacity, since the majority of work they perform is on their own fleets. This may also give a false impression of under- or over-supply of capacity. Although major US carriers could have an excess of capacity for their own fleets, their facilities do not contribute to an oversupply in the industry because they do little third-party work.

The number of known bays with narrowbody and widebody base maintenance capacity far outstrips the number required. This is the case in every global region. North America, for example, has a theoretical requirement for 140 narrowbody and 58 widebody bays to complete the require C, 4C and 8C/D checks each year. Even after escalating this by about 60% to take account of labour limitations, check scheduling and check delays the probable hangar bay requirement is less than half of the known capacity. North America alone has more than 400 narrowbody and 150 widebody base maintenance bays. The number of narrowbody bays in North America is almost enough on its own to provide capacity for the world's fleet of narrowbody aircraft.

Total global known bays for base maintenance exceed 1,100 for narrowbodies and 500 for widebodies. many of these are provided by independent maintenance organisations and large airlines which supply maintenance on a third party basis.

Major airlines in Europe are the biggest providers of maintenance capacity in the region. Air France, for example, has 24 narrowbody and 26 widebody bays. Although some of these are used for line maintenance, it compares with Europe's fleet requirement for 66-100 narrowbody and 30-60 widebody bays. SR Technics has nine narrowbody bays and five widebody bays.

This pattern is repeated in every global region for both narrowbodies and widebodies. In each case the capacity required, after taking account of factors which escalate requirements, is one third or one quarter of that actually available.

Future requirements

A growing global fleet should generate more demand for maintenance capacity. As previously discussed, longer check intervals of younger aircraft will offset the larger fleet.

The widebody fleet should generate about 10% more 4C and 8C/D checks in 2006 than in 2001. The number of narrowbody 8C/D checks will change relatively little over the same period. This will change in five years time, since many of the narrowbodies that have been delivered in recent years and are due to be delivered in the next few years, will come due for their first 8C/D checks after 2006.

Only 4C checks for narrowbodies and C checks for all aircraft will increase by a large portion in the next five years. This is because the shorter intervals of these checks will see an increase in checks performed in the few years after delivery.

Overall, narrowbody hangar bay capacity may have to increase by 20% in the next five years, but up to 35% over the next 10. This implies that nearly 500 bays will be required in five years and 550-600 in 10 years.

A smaller increase in widebody bays is likely in North America, but more than 300 bays could be required globally in 10 years.

The implications of this are that no more maintenance capacity will have to be added. In fact, the excess in capacity means there will be pressure on MH rates charged for third-party maintenance for an indefinite period.