The maintenance and management of rotable and repairable components is one of the most complicated elements of aircraft maintenance. A portion of these components are removed during heavy checks. Many factors affect the maintenance costs of these check-aligned parts.

Maintenance cost drivers of check-aligned rotables & repairables

Among the elements of aircraft maintenance, component repair and management is one of the most complicated. Components are either rotables or repairables. These two categories can in turn be divided into line replaceable units (LRUs), heavy components and those which require the extended downtime and access provided by a heavy airframe check to remove and repair them. This latter group of rotables and repairables can be termed 'check-aligned' components. The repair of these components do not form part of the job card items of the check. These components require separate consideration for their management and repair.

The management of check-aligned components is complicated, but their costs cannot be overlooked as an element of the aircraft's overall maintenance costs per flight hour (FH). It is important to consider the definition of these parts, how their repair and overhaul are managed, and what options operators have for managing their maintenance.

Definitions

Components and aircraft structures are classified by air transport association (ATA) chapter. ATA chapters that include LRU, heavy, and check-aligned items are summarised *(see table, this page)*.

Heavy components can be removed under their own separate maintenance programme and intervals. These are wheels and brakes, landing gear, auxiliary power unit (APU) and thrust reversers. These are included in ATA chapters 32, 49 and 78. ATA chapters are not the defining line between LRUs, check-aligned and heavy components. The ATA chapters for landing gear, wheels and brakes, APU and thrust reversers also have parts that are either LRUs or check-aligned. The identification of heavy components leaves LRUs and check-aligned components.

The basic distinction between LRUs and check-aligned components determines how they are treated by airlines with regard to maintenance. "LRUs are those which can be removed at the line station or during line checks, such as an overnight or weekly, or even A check," explains Rob Bruinsma, general manager aircraft component facility at AAR's long Island plant. "The remaining rotables and repairables are those which require the downtime of a heavier airframe check for removal to be possible." They are sometimes colloquially known as 'deep access' items.

The defining line between LRUs and check-aligned components is not clear for several reasons. Some airlines can decide to remove and replace components on the line, while others operating in harsh environments may require a hangar check to access the part. "An LRU is basically an easy to access component," explains Bruinsma. A check-aligned component is one that cannot easily be removed."

ATA CHAPTERS WITH ROTABLE, REPAIRABLE AND HEAVY COMPONENTS

ATA Chapter	Description	ATA Chapter	Description
21	Air Conditioning	38	Water & waste
22	Autoflight	45	Central maintenance
23	Communications	51	Structures
24	Electrical power	53	Fuselage
25	Equipment & furnishing	54	Nacelles/pylons
26	Fire protection	55	Stabilisers
27	Flight controls	56	Windows
28	Fuel system	57	Wings
29	Hydraulic power	73	Engine & fuel controls
30	Ice & rain protection	74	Ignition
31	Instruments	75	Air
32	Landing gear	76	Engine controls
33	Lights	77	Engine indicating
34	Navigation	78	Exhaust
35	Oxygen	79	Oil
36	Pneumatics	80	Engine accessories

The number of parts which are aligned with airframe checks for removal has reduced in modern aircraft. Those that are check-aligned are ones without sufficient inspection and test methods, or have unacceptable failures.

Each ATA chapter can have items from both categories. ATA chapter 25, for example, which accounts for interior equipment, has some emergency items such as oxygen bottles, first aid and cabin entertainment parts, which can be easily accessed and replaced on the line. It also has heavier galleys and galley structures that require a heavy check for removal. ATA chapter 27 for flight controls has LRUs, and others that can only be removed during heavy checks.

Donal Boylan, chief technical officer at Lombard Aviation Capital says ATA chapters 22, 23, 24, 25, 26, 29, 30, 31, 34, 35, 45, 73-77, 79 and 80 *(see table, page 31)* are essentially LRU items, although there are exceptions in each chapter.

The remaining ATA chapters that account for mainly check-aligned components are 21, 25, 27, 28, 33, 38 and 51-57 *(see table, page 31).* These include air conditioning, interior equipment, flight controls, fuel system and water systems.

Maintenance evolution

The maintenance of LRUs and check-aligned components further confuses the dividing line between them. The timing of removal and maintenance for these components varies.

Most parts had hard times for maintenance or hard lives for replacement. "Maintenance planning engineers combined the removal of most components with C or D checks," explains Henry Godiksen, manager of component engineering at SAS Component. "Half of aircraft components were deep access and so required the downtime of a D check. Because airlines looked for more flexible airframe maintenance planning the maintenance philosophy was changed so more components could be more easily accessed for repair between heavy checks."

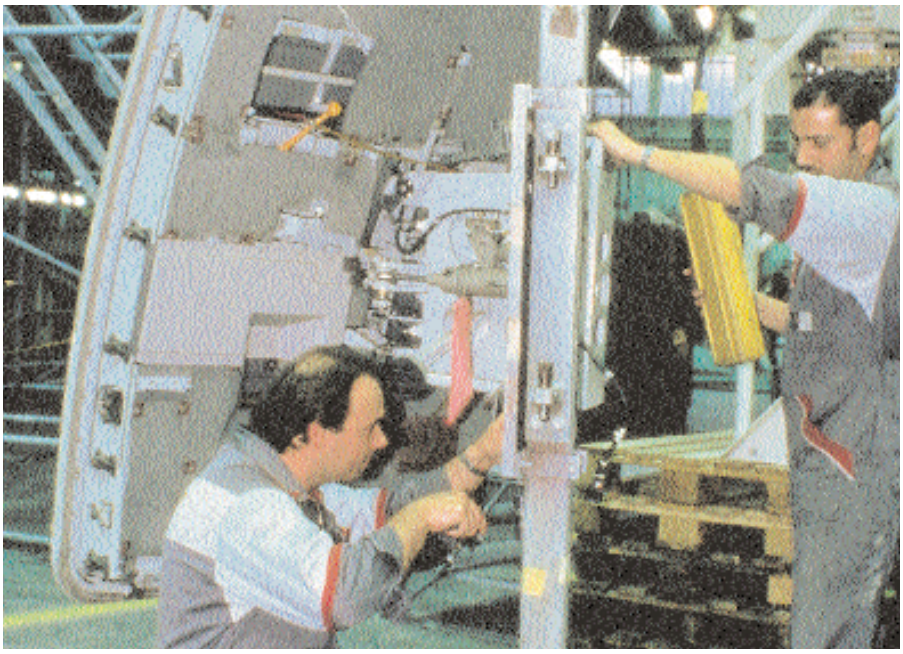
This led to the on-condition and condition-monitoring concept of components. "If it became possible to inspect a component while still on the aircraft, its maintenance could be changed from a hard time to on-condition or condition-monitored," explains Godiksen. "Components which have been left with hard time maintenance intervals are those which are impossible to inspect during lighter checks, and require the access of a heavy check. Examples are air conditioning ducts and doors. Others are those which will have unacceptable failures if they are not repaired at the fixed interval. There are also hard time components which do not have appropriate condition-monitoring inspections."

On-condition maintenance allows a component to remain on the aircraft until failure, while condition-monitored components have their performance monitored on the aircraft and then inspected and tested if their performance deteriorates.

"Initial inspection intervals are stated when aircraft are delivered," says Bruinsma "Large airlines then define their own hard times. Both airlines and independent component service providers will have reliability and quality programmes that track parts so they can schedule inspections with airframe checks. Inspection findings then allow inspection intervals to be extended and airlines can then establish 'soft times' for inspection or removal. If parts are inspected and found to be functioning satisfactorily they can be left in position until the next interval."

Although maintenance of many components has changed to on-condition and condition-monitored, they may still be check-aligned components, since they require deep access for removal. "There has been a tendency to move everything to on-condition maintenance," says David Sissons, president of AirLiance Materials. "Hard time intervals are seen as unnecessary if a part is functioning satisfactorily. On-condition and condition-monitored component maintenance therefore reduces maintenance intervals of a large number of parts and so reduces maintenance cost. An example of components that have changed from hard time to condition-monitored are flight control cables and bell cranks. These are accessed during a heavy check. Designers of modern aircraft may have anticipated the heavy check interval of six years and designed the flight control cables and bell cranks with a safety margin of 12 years. If the inspection at six years reveals satisfactory functioning the parts can be left until the next check at 12 years. The inspection interval for these deep access, condition-monitored components matches the airframe check with the appropriate interval, as well as the downtime to allow replacement. The repair schemes for components on modern aircraft, such as the 777, are simple compared to old generation aircraft, like the 727."

Despite it being possible to allow condition-monitored components to remain on the aircraft if they pass inspections and tests, Boylan explains that large airlines with large volumes of these components in their inventories will still remove them during heavy airframe checks and they are effectively condition checked off-wing. Satisfactory components can then be returned to serviceable stock until the next aircraft enters the hangar for a heavy check. Smaller airlines with small inventories or none at all, or no on-site inspection and repair capability will leave the components on the aircraft, if they are not problematic, until a heavy check.



Doors are one item that are check-aligned, since a heavy check provides the only opportunity for inspection and repair. The majority of check-aligned components are related to the flap and slat drive mechanisms, as well as fuel system components.

Component types

Components can be sub-divided into six categories. That is, there are on-condition, condition-monitored and hard time components in the categories of LRU and check-aligned parts.

A fixed interval part, for example, may be accessible during line maintenance, while another, such as air ducting or galley structures can only be easily exposed during a heavy check.

Condition-monitored and on-condition components can also be either LRUs or check-aligned components. An example of a condition-monitored LRU is the hydraulic rudder actuator. Although this can fail, and will prevent further operation, reliability is high enough to prevent failure during operation which would result in inconvenient downtime. The part can be easily accessed and replaced during an overnight or A check. This component would have been a hard time, check-aligned item in older aircraft.

Boylan points out that components in ATA chapters 25, 26, 31, 32, 35, 73 and 75 *(see table, page 31)* are mainly hard time. These are also generally LRUs.

LRUs in ATA chapters 22, 23, 24, 29, 74 and 76 are on-condition components, while ATA chapter 27 (flight controls) are on-condition, deep access items.

Condition monitored components are generally confined to ATA chapters 25, 28, 30, 33, 36, 38, 51-57, 71, 77, 78, 79 and 80. Chapter 25 (interiors) therefore has both hard time and condition-monitored components. The components in these chapters are split between LRUs and check aligned parts. Components that are check aligned include the air conditioning system, interior, flight controls, the fuel system, lights, the water system and various structures including doors, nacelles, stabilisers, and wings.

There is, however, overlap between LRU and check aligned components in every ATA chapter.

Graham Thrower, account manager of technical operations at British Airways Engineering, gives examples of check aligned components. “These include flap and slat drive units, heat exchangers, standby motor pumps, various parts in the fuel system, the toilet and waste system, air conditioning and ducting, and the engine and fire control system,” says Thrower. “Aircraft are now designed to make most rotables easy to access and remove, leaving a minority of rotables and repairables as check aligned.”

With a growing trend for more components being on-condition or condition monitored, only a small percentage of rotables and repairables are check aligned. “These probably account for no more than 15%,” estimates Thrower.

An MD-80, for example, has about 1,200 different rotable part numbers, but Godiksen estimates that only about 130 are hard time controlled.

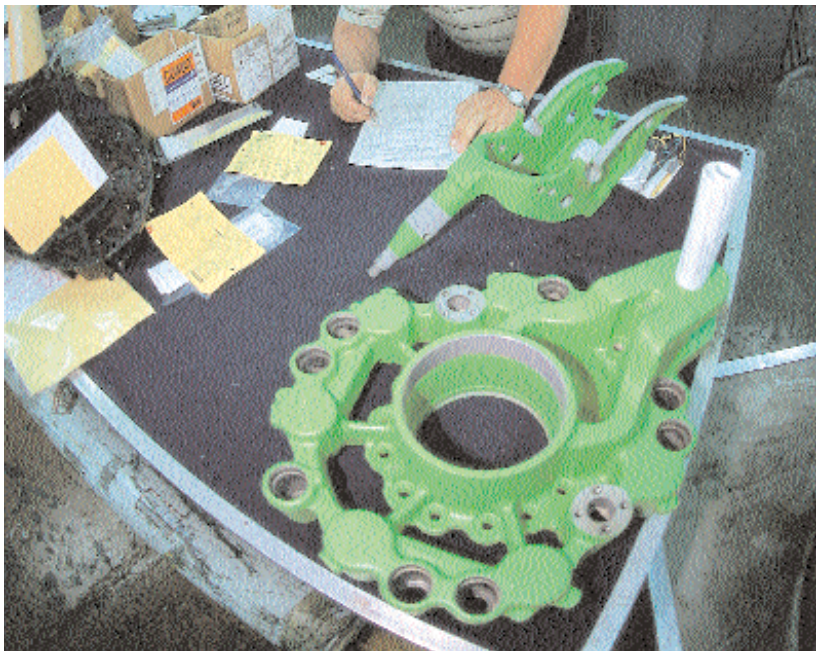
“The number of parts aligned with checks are higher older aircraft types, which have more complicated component designs,” says Thomas Orlowski, production manager heavy maintenance component support at Lufthansa Technik. “Flap drive mechanisms on the 737-200/-300/-400/-500, for example, are more complicated than on the new generation aircraft. The older 737 and 747 models have fowler flaps and these have to be check aligned, since their maintenance is too complicated to be on-condition. The components of the flap mechanisms are tracks, carriages, torque tubes, quadrants and screw jacks. The carriages are especially complicated, because each one has about 100 bushings. The same is true for the A300 and A310.

“This compares to younger Airbus and Boeing aircraft types, which do not have fowler flaps, but simple flap systems. Younger model fly-by-wire Airbus aircraft have rotary actuators, rather than carriages and screw jacks. The only other components are torque tubes. There are therefore fewer parts which are aligned with checks,” says Orlowski. “The majority of check-aligned components are related to the flap and slat mechanisms, and so aircraft with simpler flap and slat systems have fewer check-aligned parts. Examples of the few other check-aligned components are heat exchangers, and some of the items from the air conditioning system. Although the 777 uses screwjacks, it does not have carriages, and has fewer parts. The screwjacks are LRUs, and only the rotary actuators are check-aligned. In most cases, rotary actuators are on-condition, and are rarely expected to fail. In addition to the increased simplicity of these components, they are also more resistant to deterioration. Examples are the replacement of steel with titanium, making components more resistant to corrosion. Chrome plating in landing gears and steel components will be replaced with flame spraying of different materials, which again makes them more corrosion resistant.”

Some operators leave these components at heavy checks, since it is cheaper. This incurs a risk, however, since failure can occur later as a result. Freight airlines, for example, with older fleets fly until failure, and then replace components. They can do this economically because of the surplus of material on the aftermarket.

Jorg Asbrand, manager aircraft component services at Lufthansa Technik, gives the 737 as an example of the subdivision between LRUs, check-aligned and hard time components. “The 737 has about 600 LRU part numbers, 160 of which are hard time. There are about 100 hard time part numbers removed at the heavy check, about half of which are LRUs and the other half are deep access components. These 100 part numbers are equal to about 160 items in total”.

Source One Spares is an independent



Items such as flap carriages are the most complicated of check-aligned components of older aircraft types to repair. These parts do not exist in younger types, one factor which has reduced the number of check-aligned components.

spares provider which manages the repair and exchange of heavy components for airlines. "We exchange parts which are non-closed loop items, and take unserviceable parts and manage their overhauls," says John Rosson, managing director at Source One Europe. "It is often cheaper for airlines to have exchange fees and repair costs. Our service is alternative to airlines using their own in-house repair capabilities, since they are sometimes unable to meet their own turn times required to get the part back on the aircraft while it is in a hangar check. We provide services for heavier components, which get removed during hangar checks. Small and medium airlines can benefit from the high volume of repairs that we manage. We provide a complete management repair service for check-aligned components. We provide services for all McDonnell Douglas types, the 737 classics, 747-400, 757/767, 777 and A320 family. Airlines have to plan the removal of their components, but we manage them once they have been removed."

Repair schemes

Airlines have traditionally had their own backshops for the repair of components. Airlines require a high volume of component repairs to justify this, and the larger carriers sell their maintenance capacity. There are many smaller airlines that do not have their own maintenance facilities, or the facility to test, inspect, repair components or keep quality and reliability programmes.

Airlines have several choices when organising maintenance for both check-aligned rotables and LRUs. "We supply inventories of both types to customers," says Bruinsma, "and the quantity supplied is based on reliability data. Operators that do not have parts in their inventories can exchange parts with us. We provide customers with a service to remove, manage and repair components during checks. Airlines may take their aircraft for heavy checks to facilities with few back shops for component repair. In this case check-aligned components would then be sub-contracted to other repair facilities, including the manufacturers of these components. This includes companies such as TRW Aeronautical and Parker Bertea. AAR will then manage the repair of these components on behalf of our customers. We also complete supply chain management by providing consumables and expendables. For simplicity we can provide the repair and management of check-aligned components, and all rotables and repairables, in a fixed rate per flight hour (FH) contract. The inventory can either be separately owned by the airline, or leased from us. The fixed rates per FH will have separate costs for LRUs and check-aligned components."

The repair turntime of these components complicates the management of the heavy check. "Not all components, especially deep access components, can be closed loop items, explains Asbrand. "That is, they cannot be repaired in time to be reinstated on the same aircraft, so the airline operator has to check for a loan or an exchange unit. Since the availability and cost for exchange units is sometimes crucial for the heavy check, Lufthansa Technik offers a project management product called MORE+ for aircraft in checks anywhere in the world. With MORE+ we make all components guaranteed available at a fixed price including the repair or exchange cost, if necessary. For customers already under an exclusive component support contract with Lufthansa Technik, most of the removals from a heavy check are already covered by the power-by-the-hour agreement. All others will be repaired or overhauled on a fixed labour price basis and exchange fees will be applied for parts which are not closed loop."

AirLiance Materials is another component supplier that offers fixed rate schemes to airlines to manage and repair check-aligned components. "It is hard for airlines with their own shops to determine what their costs for repairing and managing these parts are, but independents have to know the costs to survive," says Sissons. "Besides repair and management of these components we will also arrange exchanges for individual components, or a combination of inventory management and exchanges as the client requires. It is quite common for airlines to pay a fixed rate per FH for the management of all LRUs and check-aligned components."

"We prefer not to offer power-by-the-hour (PBH) deals," says Rosson. "Damages to components vary, and the cost of PBH is often higher than the real cost of management and repair. Instead we do one-off costs, using either time and material or exchange fees. We have ex-Boeing engineers which manage parts in reference to their dash numbers. That is, they can advise airlines about which parts can and cannot be modified for their aircraft. Airlines used to just new parts from the manufacturers if they were unsure about which parts they could modify. We can thus save them costs."

Repair & management costs

Fixed rates per FH for the repair and management of these components varies, and individual contracts will also vary for each airline. Estimates for the 747 are $200 per FH, the A330 and 777 both about $125 per FH, the 767 and A300-600 about $100 per FH and 757, A320 and 737NG all in the region of about $75 per FH.

These parts will be added to by the cost of man-hours and materials used in airframe checks, and also the cost of owning or leasing, repairing and managing LRU inventories.