Issue 2 - January 2008

getting to grips with

A320 Family performance retention and fuel savings

AIRBUS

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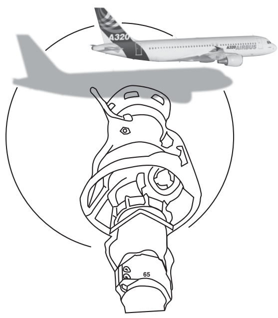

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Dear Operator,

We have all seen the price of jet fuel climb significantly in recent times. In reaction to this, many Airlines have reviewed and revised certain procedures in an effort to minimize the impact of this phenomenon on their operations.

In support of this, there is a multitude of information published by both the Aircraft Manufacturers and Industry bodies describing the mechanisms by which fuel can be economized.

This document represents the latest contribution from Airbus. The document was designed to provide a holistic view of the subject from the manufacturers' perspective. In producing the document we brought together specialists from the fields of aircraft performance, aerodynamics and engine and airframe engineering, and integrated their inputs that were born out of their wide experience with in-service aircraft. The aim was and is to share best practices by providing you with a guide to selected initiatives that can reduce both the fuel bill and the operating cost of your A320 Family aircraft. You will find brief discussions of the various initiatives that highlight both their pros and cons.

The document was first published in October 2006. With this second issue we expand the discussion of some points and initiatives, following the feedback we received and introduced the subject of environmental considerations and an initiative summary table in the conclusions (all the principle changes can be identified by a vertical line in the page margin).

We wish to express our thanks to those within and outside Airbus who have contributed to this brochure.

Should you need further information you will find contact details adjacent to each of topics covered by this brochure.

Best regards,

Antoine Vieillard
Vice President A320 Family
& CJ/ VIP Programme
Customer Services

Jacques Drappier
Vice President Flight Operations
Support and Services

1 SCOPE

This document has been written to highlight the basic principles of, and main contributors to, fuel efficiency for in-service aircraft, using the A320 Family as a specific example. Its objective is to help raise general awareness of the subject throughout the airline and beyond. The document does not seek to push fuel efficiency measures on the operator but to highlight them and provide a basis for the study of their implementation within the operation.

The document has been written principally from the perspective of the aircraft, its operation, maintenance and servicing. However, where appropriate, mention is made of other influencing factors, such as scheduling or passenger service level. Environmental issues are becoming increasingly important and these too have been outlined. References and points of contact within Airbus are provided throughout for those wishing to explore any item more fully.

2 INTRODUCTION

Figure 2-1
Elementary forces on an airframe

Elementary physics tell us that for an aircraft to fly it must generate lift to overcome its weight. Generating lift produces drag, (as does the movement of the airframe through the air). The engines generate the thrust necessary to overcome the drag. The greater the thrust required the more fuel is burnt. This document discusses methods of minimizing that fuel burn.

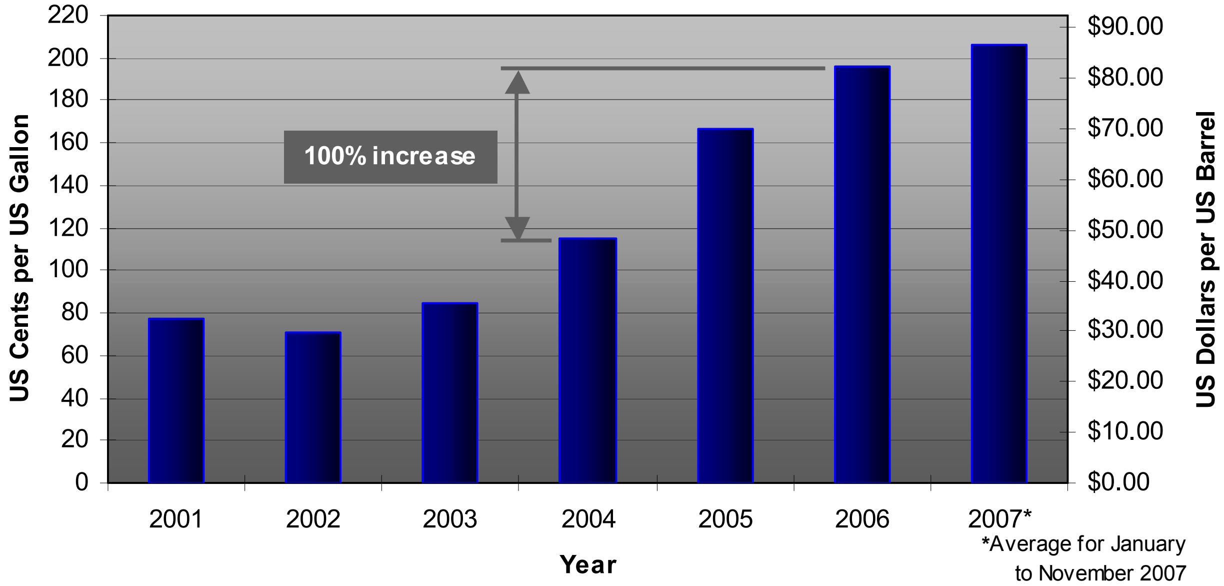


Figure 2-2
ATA Jet Fuel Report – Annual Average Cost
(U.S. Majors, Nationals & Large Regionals— All Services)

The dramatic increase in jet fuel cost in recent years has had a significant effect on the division of operating costs. In 2003, jet fuel was around US$0.85 per US Gallon. At that time, fuel represented about 28% of the total operating cost for a typical A320 Family operator. By 2006 fuel prices had more than doubled, meaning that fuel now represents around 43% of all operating costs.

Focus on Fuel Price Trends
During the early years of the new millennium jet fuel prices were relatively stable. However, at the end of 2003 prices started to increase sharply. In 2005 the average price was twice that of the 2003 average. In the United States, September 2005 brought hurricanes Katrina and Rita and prices briefly reached a level 150% higher that the 2003 average. Post-hurricane prices fell but the overall upward trend continued and the 2006 average price was almost 20% higher than the previous year. The end of 2007 has produced new record high fuel prices.

Note: the jet fuel prices presented in this brochure refer to the US market but prices in other markets around the world show the same overall trends.

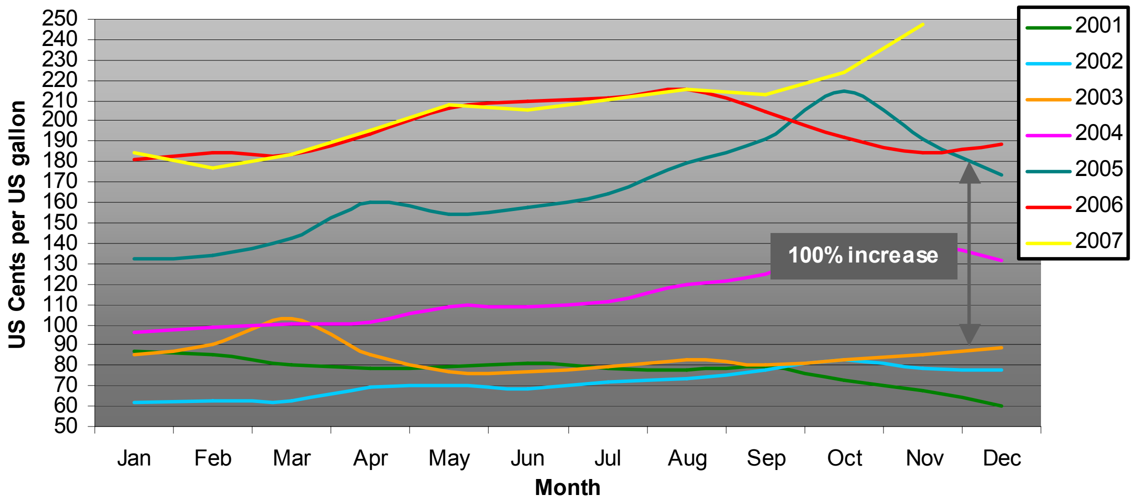
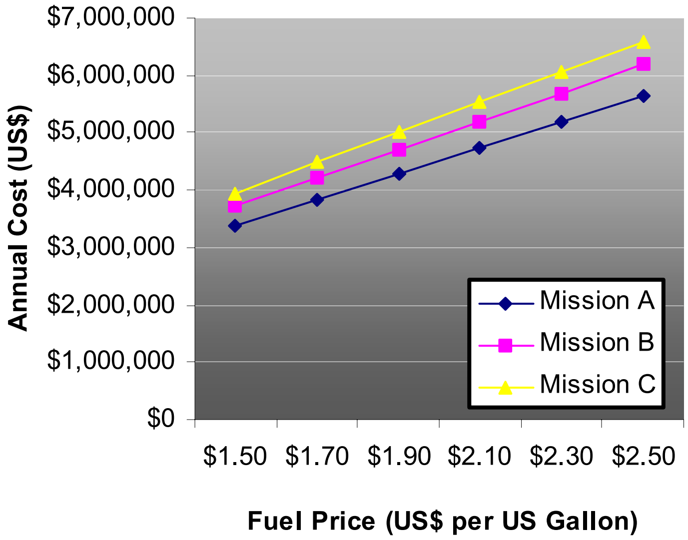


Figure 2-3
ATA Jet Fuel Report – Annual Average Cost
(U.S. Majors, Nationals & Large Regionals— All Services)

An aircraft of the A320 Family will typically consume between 3.5 and 8 tonnes of fuel (approximately 1200 to 2700 US Gallons) per flight – depending on flight distance, payload, specific aircraft type and a multitude of other parameters, many of which are discussed in this document. The chart below illustrates the annual expenditure in fuel for an A320 in three typical missions (defined in the adjacent table) and how that annual expenditure will vary with changes in fuel price. A third table indicates the factors that should be applied to determine the costs for other members of the A320 Family (in the specified missions).



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3

Note: these mission profiles are used through this brochure to provide a cost based context to many of the issues discussed.

- Annual Fuel Consumption - Average Percentage Variation from A320			
A318	A319	A320	A321
90%	**91%**	**100%**	**111%**

Figure 2-4
Annual Fuel Consumption – A320 Family

Airlines with fuel hedging policies may have been able to postpone or reduce the effects of price increases but others will have been exposed to the full impact since the beginning. The airline industry is highly competitive and many operators have sought ways to avoid passing these costs onto their customers. The identification of practices or procedures that could save money can be a time consuming process and there may be a tendency to fall back on past experience. However, given the change in operational cost breakdown, fuel economy initiatives that were previously considered as marginal may merit re-examination.

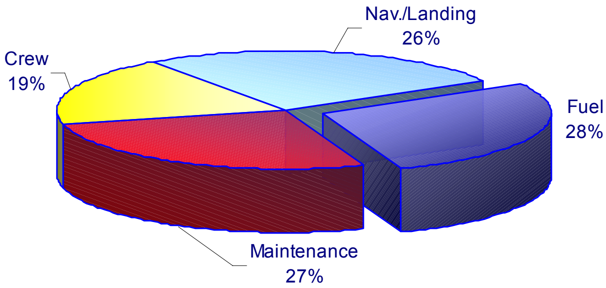


Figure 2-5
Cost of Operation Breakdown 2003
(Fuel at US$ 0.85/US Gallon)

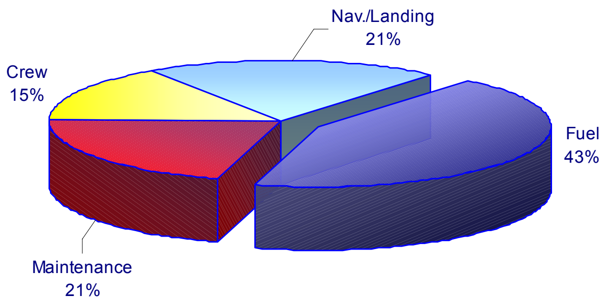


Figure 2-6
Cost of Operation Breakdown 2006
(Fuel at US$ 1.96/US Gallon)

Much has been written to support Airlines in wishing to minimize their fuel costs. Industry bodies and manufacturers have both made contributions. Airbus' principle contribution in this field has been the development of a number of documents under the generic title of, "Getting to Grips". These documents provide an in-depth insight into topics such as cost index, aerodynamic deterioration and fuel economy. For further details refer to the text box on the following page.

This document has been written as a further aid to operators of Airbus A320 Family of aircraft. It is a compilation of best practices, derived from the in-service experience of Airbus and its Customers. As such, it aims to provide, for a broad range of aircraft standards and a wide variety of operations, concise advice on the operation and maintenance practices that have been shown to limit in-service performance degradation and facilitate efficient operations.

The recommendations cover operational, maintenance and servicing aspects that, in some cases may have implications for the service the operator offers its customers. For example, the removal of galley components is discussed on page 49. Equally, on longer routes, the option offering a service that "stops-off" at another destination along the route, rather than flying directly to the final destination, offers the potential of fuel saving (because the weight of fuel required to reach the intermediate destination is less than that required to reach the final destination). Similarly the choice of flying at a non-optimum speed (e.g. flying faster to reduce crew costs or recover a delay) must balance the change in fuel consumption against the change not only in crew cost but also against the basic cost of reduced aircraft availability (either for flights or maintenance). These examples help to illustrate that adopting a holistic or airline-wide approach, as opposed to making fuel economy the responsibility of any single entity in the organization, will best serve an operator wishing to minimize its fuel bill.

Getting to Grips... brochures

The following titles are available and cover all Airbus types:

Direct influence on Fuel Economy	Issue No.	Issue Date	Available in
Getting to grips with Fuel Economy	4	Oct-04	English
Getting hands-on experience with aerodynamic deterioration	2	Oct-01	English
Indirect influence on Fuel Economy			
Getting to grips with the Cost Index	2	May-98	English
Getting to grips with Aircraft Performance	1	Jan-02	English, Chinese
Getting to grips with Aircraft Performance Monitoring	1	Jan-03	English
Getting to grips with Weight and Balance	1	Feb-04	English
Getting to grips with MMEL/MEL	1	Jul-05	English, Chinese, Russian
Other titles			
Getting to grips with ETOPS	5	Oct-98	English
Getting to grips with Cold Weather Operations	1	Jan-00	English
Getting to grips with Cat II / Cat III operations	3	Oct-01	English
Getting to grips with FANS	3	Apr-07	English, Chinese
Getting to grips with Flight Operations Monitoring	5	Sep-07	English
Getting to grips with Aircraft noise	1	Dec-03	English
Getting to grips with Datalink	1	Apr-04	English, Chinese
Getting to grips with Fatigue and Alertness Management	3	Apr-04	English
Getting to grips with Modern Navigation	5	Jun-04	English, Chinese
Getting to grips with Cabin Safety	1	Mar-05	English, Chinese
Getting to grips with Approach and Landing Accidents Reduction	1	Oct-00	English, Chinese, Russian

All these documents are available in Adobe PDF format on the Airbus World website, http://www.airbusworld.com (please note that access to this site is restricted – your Airbus Resident Customer Support Manager or Customer Support Director can provide you with connection details).

Important Note: none of the information contained in the 'Getting to Grips' publications is intended to replace procedures or recommendations contained in the Flight Crew Operating Manual (FCOM), but rather to highlight the areas where maintenance, operations and flight crews can contribute significantly to fuel savings.

Point of contact: guy.di-santo@airbus.com

Figure 2-7
Other "Getting to Grips..." brochures

3 INDUSTRY ISSUES

Fuel conservation is an issue for many groups in commercial aviation. Motivation to deal with the subject comes not only from the desire to minimize fuel expenditure, but also from the wish to address environmental concerns(after all, in simplistic terms, the best way to reduce any emissions that may be produced during flight is to burn less fuel).

Aircraft manufacturers, in co-operation with their suppliers, must design and deliver the most economically efficient and environmentally friendly aircraft possible (see following section). Operators must keep the aircraft in good condition and ensure that they are operated efficiently. Aviation authorities and associated industry bodies must provide operators with the means to fly the most efficient routes.

The object of this document is to focus on issues where positive actions can result in tangible gains at the end of the year. An average fuel conservation as low as 0.1% per flight will still add up to a tangible financial gain at the end of the year.

Unfortunately, optimum operational conditions can be compromised by Air Traffic Control (ATC) requirements, . It may be argued that efforts made to conserve fuel can be negated if the aircraft is, for example, kept waiting on the taxiway, restricted to non-optimum flight altitude by an ATC requirement or simply not permitted to fly the most direct route. Such constraints will always be a feature of commercial aircraft operations to a certain extent. However, ATC reform and modernization continues. Industry bodies such as the ATA and IATA continue to work in this area, as do individual operators. For example IATA has its Fuel Efficiency Campaign that seeks fuel savings through a combination of route improvements, infrastructure enhancements (including a fuel quality assurance program), reduced flight times and operational efficiency recommendations.

In the shorter term, Operators may find it beneficial to review their operation requirements and capabilities with their local ATC authorities to both raise mutual awareness and identify opportunities for route and schedule optimization.

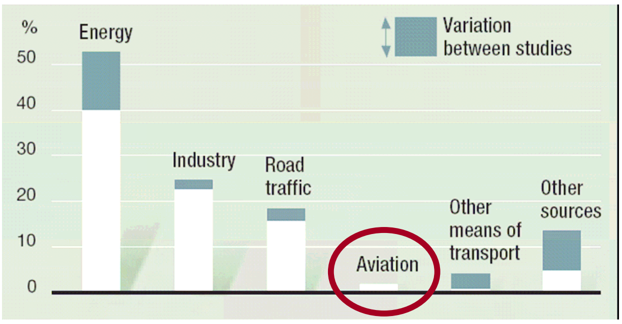
Further reading
Guidance Material and Best Practices for Fuel and Environmental Management – published by IATA, 1st Edition December 2004.
Web sites
IATA: http://www.iata.org
ATA: http://www.airlines.org/

3.1 ENVIRONMENTAL ISSUES

Like almost every business on earth, the business of operating aircraft has an impact on the environment.

The consequences of aircraft operation that are typically of general concern are the emissions from the engines and aircraft noise. A further source of concern is the use, handling and disposal of certain materials that are encountered when maintaining aircraft (e.g. asbestos, chromates). Like aircraft noise, these aspects are not directly related to fuel efficiency but they are mentioned in this section to give a more complete picture of environmental issues (the document and web sites referenced below offer further reading on these aspects).

Focus on CO_2
Carbon Dioxide (CO_2) is a product of the chemical reaction that takes place when burning any mixture of air and a petroleum-based product. Jet turbine engines produce around 3 KGs of CO_2 for every KG of jet fuel burnt. At this point it is worth noting that today, aviation as a whole, accounts for only 2% of worldwide CO_2 emissions (this is forecast to reach 3% by 2050).



Sources: IPCC, UNFCCC, IEA and DLR

Figure 3.1
Contribution to man-made carbon dioxide emissions (findings of several studies)

Focus on NO_X
NO_X, or nitrogen oxides, are another bi-product of burning fuel in an engine. Like CO_2, they are believed to have a detrimental effect on the world's environment. In recognition of this, the airports of some nations adjust their landing charges according to the amount of NO_X produced by the aircraft (as defined in the certification datasheet). Airbus aircraft have always been equipped with state-of–the-art engines offering among the lowest NOx levels in their class.

When any fossil fuel (gas, coal, oil) is burnt in air, the chemical reaction that takes place produces heat (that an engine will convert into power) and gaseous bi-products. These gases are principally carbon dioxide (CO_2) and various oxides of nitrogen (NO_X). While these gases occur naturally, it is the additional man-made contribution that is widely believed to have detrimental effects on the environment. In global terms, the aviation industry's consumption of fossil fuel and the consequential production of CO_2 are very small (see adjacent text box, Focus on CO_2), but the fact that the resulting emissions occur, in part, at high altitudes, has placed greater focus on the industry.

Studies into the use of alternative fuels that offer the potential of reduced environmental impact are underway. Before these technologies can make a difference, they must be developed for the rigors of aircraft operations (currently the freezing point of these fuels is too high for high-altitude operations). Furthermore, the implications of their

Further Reading
Getting to grips with Aircraft noise – Issue 1, December 03
Points of Contact:
Engine: jean-paul.pourtau@airbus.com
Maintenance: jean-baptiste.gambini@airbus.com
Web sites
Airbus: www.airbus.com/en/corporate/ethics/environment/index.html
ICAO: www.icao.int/env
Other: www.enviro.aero

long-term use on engines and fuel systems must be understood and the infrastructures to produce and distribute these fuels must be developed.

Airbus is committed to the development of the most fuel efficient aircraft (those on the drawing board and those currently in production), alternative fuels and the elimination of harmful materials in its aircraft, their manufacture and maintenance. Airbus also continues to develop recycling opportunities throughout its business and for its aircraft, when they are eventually withdrawn from service.

4 INITIATIVES

4.1 INTRODUCTION

Efficient aircraft operations require the careful integration of many factors including regulatory restrictions, en-route and airport traffic control requirements, maintenance, aircrew and fuel costs.

Systematic, effective flight planning and careful operation and maintenance of the aircraft and its engines are essential to ensuring that all requirements are properly addressed and that the aircraft is consistently being used in the most efficient way possible.

Like all complex machines, the aircraft, as it progresses through its operational life, will experience a performance degradation. Careful operation and maintenance can limit this degradation.

This section is the largest section of the document and provides advice on basic aircraft operations, operational procedures and aircraft maintenance. Initially, fundamental operational principles are discussed. This is followed by specific procedures that can be used at various phases of the flight to optimize efficiency. The maintenance sections discuss the timely resolution of specific defects that have a notable impact on fuel consumption. Finally, proposals for reducing aircraft weight can be found. It is important to note that the implementation of a given proposal may affect costs elsewhere in the operation. These aspects are also highlighted within the discussion of each fuel saving initiative (see also, Focus on Balancing Costs, text box on page 28).

Charts have been included to illustrate the potential fuel savings a given initiative will bring. The savings, in terms of kilograms of fuel per sector, are shown for three typical missions (shown in the adjacent table). For convenience these savings have also been transformed into annual or monthly dollar savings for a range of jet fuel prices.

Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3

Figure 4-1
Color code and parameters of the 3 typical missions referred to throughout this document

It should be borne in mind that in some cases, the savings in fuel must be balanced against potential cost increases elsewhere in the operational cost breakdown. This balance is highly dependent on the operational environment. As such, this document highlights the factors that may change, but it does not attempt to quantify them. To illustrate this, the example of flying the aircraft at a lower speed can be used. Flying more slowly may reduce fuel burn but it will increase flight time. This will increase crew and other time related costs.

4.2 OPERATIONAL INITIATIVES

4.2.1 AIRCRAFT OPERATIONS

Efficient flight planning, which accurately predicts and optimizes overall performance, is a key contributor to minimizing costs. Accurate Computerized Flight Plan (CFP) production is a crucial element in achieving this. CFPs are produced, as the name suggests, using commercially available software or they may be obtained directly from a specialist sub-contractor.

Following a CFP and using appropriate factors in the Flight Management and Guidance System (FMGS), will help to:

- Minimize direct operating costs,
- Build Flight Crew confidence that fuel reserves will be intact on arrival and reduce tendencies to load extra fuel.

Two simple ways of reducing fuel consumption are optimizing airspeed and altitude. However, these two conditions may be difficult to achieve in an operational environment. Usually a compromise must be found between fuel burn and flight time on one hand and ATC constraints on the other. In any case, these aspects must be considered from the start and kept in mind throughout.

Note: in the interest of clarity 3 cost axes are used in the charts accompanying the operational initiatives discussed. To highlight the variation a fixed US$20,000 cost reference line (→ **US$20,000** *) has been added to each chart.*

4.2.2 COST INDEX

The Cost Index represents the trade-off between the cost of time (crew costs, aircraft utilization and other parameters that are influenced by flight time) and the cost of fuel. It is used to minimize the total cost of a flight by optimizing speed to obtain the best overall operating cost. Although fuel represents a high cost per flight it can still be more cost effective overall to fly faster, burning more fuel, because of a high cost of "time". A cost index of zero will have the aircraft fly at its maximum range capability (i.e. most fuel efficient speed), conversely a maximum cost index will have the aircraft flying at maximum speed (i.e. minimum flight time).

AirS@vings
Airbus has recently launched a new software tool called AirS@vings. It is designed to provide a dynamic determination of the cost index under a wide variety of operational criteria so that it can be accurately tailored to the specifics of an airline's operation on a particular route.
Point of Contact: jean-jacques.speyer@airbus.com

The Cost Index parameter is entered into the aircraft's Flight Management System (FMS) and may be varied to reflect the specific constraints of a given flight. Operators

Reference documents
Getting to Grips with the Cost Index – Issue 2 May 1998
Point of contact: fltops.perfo@airbus.com

wishing to optimize their Cost Index, either for their global operation, or for specific sectors, will need to make assessments of all relevant operating costs. Only when this has been done can an appropriate Cost Index (or Indices) be determined.

An operator who has completed a Cost Index review may find that the revised figures that have been developed cannot be fully implemented within the current schedule because flight times may have increased.

4.2.3 FUEL ECONOMY

The following factors effect fuel consumption:

- Cruise speed (see section below for further details)
- Flight level (see section on page 17 for further details)
- Flight Plan accuracy (see section on page 18 for further details)
- Aircraft performance degradation (see section on page 18 for further details)
- Fuel reserves (see section on page 19 for further details)

Accurate tuning of the flight planning system to the aircraft's performance and, wherever possible, accurately flying the aircraft in accordance with the Flight Plan may only bring a small gain on each flight, but these small gains can add up to a measurable gain at the end of the year.

One important objective that is worth repeating is the ***building of pilot confidence in the Computerized Flight Planning (CFP)***. The production of an accurate flight plan will precisely predict actual fuel usage and will remove any tendency by the pilot to *add some extra* fuel reserves on top of those already calculated.

Reference documents
Getting to Grips with Fuel Economy – Issue 4 October 2004
Point of contact: fltops.perfo@airbus.com

4.2.3.1 CRUISE SPEED

The cost index selected for a given flight will determine the speeds and hence the time needed to cover the journey's distance. The speed must be optimized for the flight conditions to minimize the overall operating cost.

Realistic fuel consumption predictions can be obtained using Airbus' Performance Engineering Program (PEP) software (refer to text box on page 16), for speeds and flight-levels as a function of a given cost index, aircraft weight, and wind conditions.

Reference documents
Getting to Grips with Fuel Economy – Issue 4 October 2004
Getting to Grips with Aircraft Performance – Issue 1 January 2002
Point of contact: fltops.perfo@airbus.com

However, in practice, the fuel consumption prediction of the Flight Plan can only be achieved if:

- the cost index and speed (and altitude – refer to following section for further details) parameters stated in the Flight Plan are accurately followed,
- the Flight Plan is an accurate representation of the flight to be undertaken.

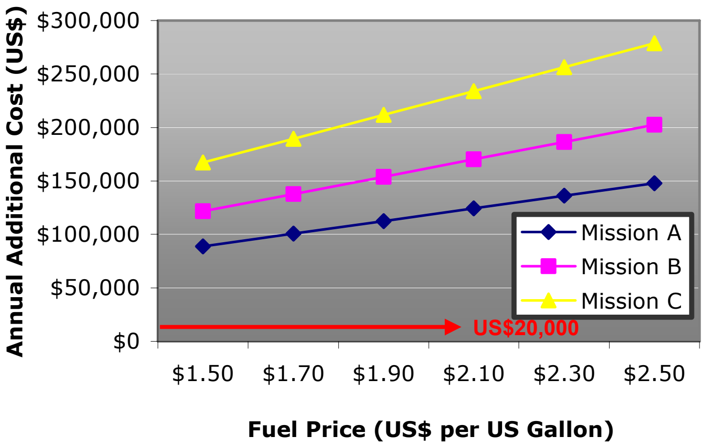


Figure 4-2
Increase of 0.02 Mach Number (0.78 to 0.80)

Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Additional fuel per sector (KGs):	**98**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Additional fuel per sector (KGs):	**161**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Additional fuel per sector (KGs):	**302**

Airbus Performance Engineering Program (PEP) Software Package
Several references to this software package are made throughout this document. Similar software packages are available from other aircraft manufacturers but the proprietary nature of the data makes the package applicable to the supplier's products only. As such, Airbus PEP software provides unrivalled degree of precision in the optimization of efficient operations of its aircraft.

The Airbus PEP is comprised of several modules:

Flight Manual (FM): the FM module of PEP represents the performance section of the Flight Manual in a digital format for all aircraft (not available for A300).

Takeoff and Landing Optimization (TLO): takeoff calculation gives the maximum takeoff weight and associated speeds for a given aircraft, runway and aircraft atmospheric conditions. The takeoff performance computation is specific to one airframe/engine/brakes combination. The takeoff calculation computes takeoff performance on dry, wet and contaminated runways (except A300 B2/B2K/B4), taking into account runway characteristics, atmospheric conditions, aircraft configuration (flap setting) and some system failures.
Note: runway and obstacle data are not provided by Airbus.

Flight Planning (FLIP): produces fuel predictions for a given air distance under simplified meteorological conditions. The fuel prediction accounts for operational fuel rules (diversion fuel, fuel contingency, etc.), for airline fuel policy for reserves and for the aircraft performance level. Typical fields of application are technical and economical feasibility studies before opening operations on a route.

In Flight Performance (IFP): computes general aircraft in-flight performance for specific flight phases: climb, cruise, descent and holding. The IFP works from the aircraft performance database for the appropriate airframe/engine combination. The IFP can be used to extract digital aircraft performance data to be fed into programs specifically devoted to flight planning computation.

Aircraft Performance Monitoring (APM): evaluates the aircraft performance level with respect to the manufacturer's book level. Based on a statistical approach, it allows the operator to follow performance degradation over time and trigger maintenance actions when required to recover in-flight performance. This tool measures a monitored fuel factor which is used to update the aircraft FMS "PERF FACTOR" as well as the fuel consumption factor for the computerized flight plan.

Operational Flight Path (OFP): this module is designed to compute the aircraft operational performance. It provides details on all engine performance and also on engine out performance. This engineering tool gives the actual aircraft behavior from brake release point or from any point in flight. It allows the operations department to check the aircraft capabilities for flying from or to a given airport, based on operational constraints (Noise abatement procedures, standard instrument departure, etc.) (Not available for A300).

PEP brochure: http://www.content.airbusworld.com/SITES/Customer_services/html/acrobat/pep.pdf
Point of Contact: fltops.perfo@airbus.com

Figure 4-3: Airbus Performance Engineering Package (PEP) Software

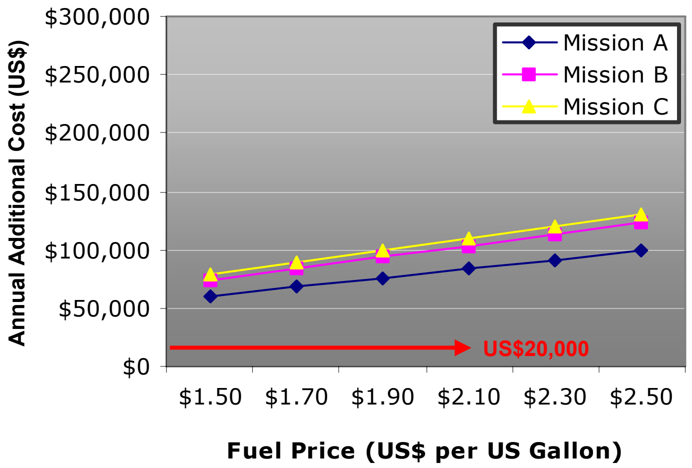
4.2.3.2 FLIGHT LEVEL

As with most modern commercial jet engines, those fitted to aircraft of the A320 Family are at their most efficient at high altitude. The Optimum Flight Level is the altitude that will enable the aircraft, at a given weight, to burn the lowest amount of fuel over the entire flight. It can be accurately computed for a given flight distance using the In-Flight Performance (IFP) module of the Airbus Performance Engineering Program (PEP) software package (see text box on previous page for more information). This information should systematically be incorporated into the Flight Plan.

ATC constraints may prevent flight at this optimum altitude, but the principle should be accurately followed whenever possible. Nonetheless, the Flight Plan should always be an accurate representation of the actual flight being undertaken and include all known ATC constraints.

Reference documents
Getting to Grips with Fuel Economy – Issue 4 - October 2004
Getting to Grips with Aircraft Performance – Issue 1 - January 2002
FCOM Volume 3.05.15
Point of contact: fltops.perfo@airbus.com

It can sometimes be appropriate to change altitude during the flight since difference in wind speeds can be significant enough to affect the aircraft's specific range. Information on this phenomenon can be found in the wind/altitude trade tables in the Flight Crew Operating Manual - volume 3. This data is also available in the Flight Management System (FMS).



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Additional fuel per sector (KGs):	**66**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Additional fuel per sector (KGs):	**98**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Additional fuel per sector (KGs):	**141**

Figure 4-4
2000 Ft below optimum Flight Level

4.2.3.3 FLIGHT PLAN ACCURACY

In terms of aircraft operation, an accurate, Computerized Flight Plan (CFP) is one of the most important means of reducing fuel burn.

As is the case with most computer systems, the accuracy of the data provided to a CFP system will influence the accuracy of the CFPs it produces. However, the nature of some of the parameters can bring a certain degree of inaccuracy.
For example:

- Weather conditions: particularly temperatures and wind strengths/directions.
- Fuel specification (lower heating value): defines the heat capacity of the fuel standard fuel. Engine thrust depends on the amount of heat energy coming from the fuel it is burning. The aircraft database may contain a standard or average value that may not correspond to the actual fuel used. A fuel analysis or data from the fuel provider can provide the necessary clarification.
- Inclusion of actual ATC constraints.
- Up-to-date aircraft weight: aircraft weighing is a scheduled maintenance action and the latest data should be systematically transferred to the CFP system.
- Payload estimation: assessment of passenger baggage and cargo variations with route and season.
- Aircraft performance degradation: refer to following section.
- Fuel reserves: refer to section 4.2.3.5 on page 19.

4.2.3.4 AIRCRAFT PERFORMANCE DEGRADATION

With time the airframe and engine deteriorate and the aircraft requires more fuel for a given mission. These deteriorations can be partially or fully recovered through scheduled maintenance actions. Deterioration will begin from the moment the aircraft enters service and the rate will be influenced by the utilization and operation of the aircraft.

The Aircraft Performance Monitoring (APM) module of the Airbus Performance Engineering Program (PEP) software package (see text box on page 16 for more information) allows aircraft degradation with time to be calculated. It can also be used as a means of triggering maintenance actions to recover some of the degradation.

The implementation of an Aircraft Performance Monitoring program requires the processing of data through the APM software. The required data, known as “cruise points”, are automatically recorded by the aircraft. Depending on the aircraft’s configuration, the transfer of these data can be achieved via either printouts from the cockpit printer, a PCMCIA card or diskette, or via the ACARS system.

The performance degradation for each individual aircraft is an important parameter. Accurate interpretation of this factor will enable the fuel usage predictions of the Flight Management System (FMS) to better match those of the CFP system.

Knowledge of performance levels can also facilitate an operator's discussions with their local Airworthiness Authority regarding the decrease of fuel reserves from a general 5% of the trip fuel to 3%.

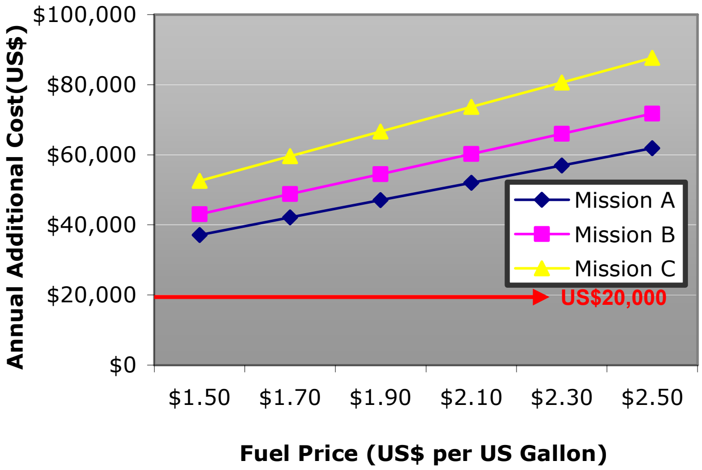
Reference documents
Getting to Grips with Aircraft Performance Monitoring – Issue 1, January 2003
Point of contact: fltops.perfo@airbus.com

4.2.3.5 FUEL RESERVES

Part of any extra fuel transported to a destination is just burnt off in carrying itself. It is not uncommon for operators to uplift additional "discretionary" fuel beyond that called for by the Flight Plan. This policy is often simply a result of a lack of faith in the fuel usage predictions made by the flight planning system.
Of course, when reserves beyond those described in the flight plan are added, the flight plan predictions automatically become invalid.

Reserve requirements vary between aviation authorities. Some Aviation Authorities allow a procedure known as "Reclearance in Flight" on some routes. This procedure can reduce the reserves required for a given route and should be considered when appropriate. All fuel reserves, including discretionary reserves, should be included in the Flight Plan.

Reference documents
Getting to Grips with Fuel Economy – Issue 4 October 2004
Getting to Grips with Aircraft Performance – Issue 1 January 2002
Point of contact: fltops.perfo@airbus.com



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Additional fuel per sector (KGs):	**41**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Additional fuel per sector (KGs):	**57**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Additional fuel per sector (KGs):	**95**

Figure 4-5
Additional 1000 kg of fuel reserve

Aircraft Operations Fuel Conservation Action Overview

The following actions have been described in the preceding sections and should be implemented to ensure a systematic reduction in fuel consumption on each flight:

- Calculate Computerized Flight Plan (CFP) with Cost Index of flight,
- Accurately follow the speed and altitude schedules defined by the CFP,
- Regularly monitor aircraft performance to determine performance factors to be used by Flight Management System (FMS) and CFP system and to identify aircraft performance trends,
- Use Airbus PEP software to validate optimum speeds and altitudes used in CFP,
- Optimize and regularly validate all other CFP system parameters,
- Review fuel reserve requirements with local authorities and optimize for each flight,
- Minimize discretionary fuel reserves and include all reserves in CFP.

4.2.4 OPERATIONAL PROCEDURES

Having considered the principle factors that can influence fuel consumption we now consider operating procedures that can also play a part in reducing either the fuel bill or the operational cost.

4.2.4.1 FUEL TANKERING

Reference documents
Getting to Grips with Fuel Economy – Issue 4 October 2004
Point of contact: fltops.perfo@airbus.com

Usually the message is, to minimize fuel burn it is most economical to carry the minimum required for the sector. On the other hand, there are occasions when it is, in fact, more cost effective to carry more fuel. This can occur when the price of fuel at the destination is significantly higher than the price at the point of departure. However, since the extra fuel on board leads to an increase in fuel consumption the breakeven point must be carefully determined.

Graphs in the FCOM and the PEP FLIP module (see text box on page 16 for details) assist in determining the optimum fuel quantity to be carried as a function of initial take-off weight (without additional fuel), stage length, cruise flight level and fuel price ratio. Software designed to optimize the effectiveness of fuel tankering is also commercially available and Airbus' AirS@vings software (mentioned on page 14) also provides an assessment of tankering economic efficiency.

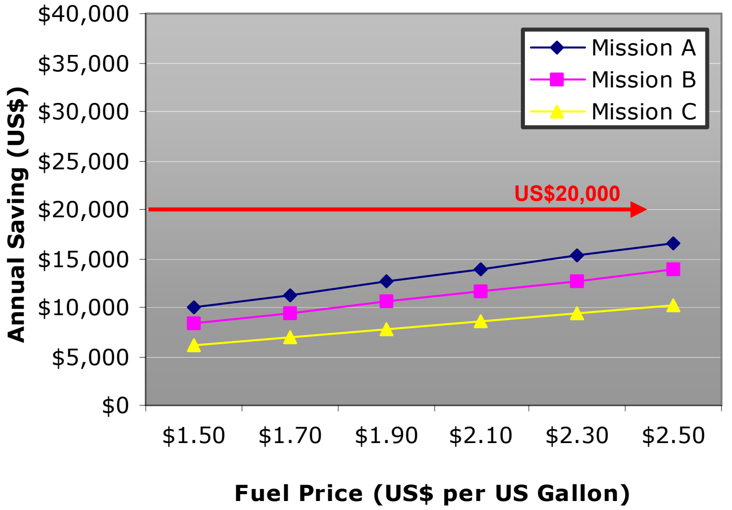
4.2.4.2 APU USE

Reference documents
Getting to Grips with Fuel Economy – Issue 4 October 2004
Point of contact: fltops.perfo@airbus.com

Ground power and air are usually significantly cheaper per hour than the APU (when considering both fuel and maintenance costs). Consequently the moment of APU and engine start should be carefully optimized with neither being switched on prematurely. Calculating average APU usage per sector can be a useful monitoring tool.

The availability and use of ground equipment for the provision of both air and electrical power should be re-evaluated at all destinations and the possibility of obtaining and operating additional ground equipment where necessary should not be dismissed without evaluation.

The following example illustrates the cost of jet fuel for 5 minutes of APU use. In addition it should be noted that during these 5 minutes the APU would also produce around 35 KGs of CO_2 (refer to text box "Focus on CO_2" on page 10 for further details).



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Fuel saved per sector (KGs):	**11**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Fuel saved per sector (KGs):	**11**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Fuel saved per sector (KGs):	**11**

Figure 4-6
Five minutes less APU use per flight

4.2.4.3 ENGINE WARM-UP AND COOL-DOWN PERIODS

Reference documents
FCOM Volume 3
Point of contact: fltops.perfo@airbus.com

An engine from on an A320 Family aircraft weighs approximately 1 ton and consequently it takes time for all components to reach their operating temperature. Furthermore the various components will expand and contract with temperature at difference rates. Minimum warm-up and cool-down periods have been determined to allow the engine to expand and contract in a more linear way and thus avoid unnecessary heavy or asymmetric rubbing. Such rubbing will increase running clearances that in turn will lead to losses in efficiency and increased fuel consumption.

Condition		**Procedure** *(for reference only – this document does not replace or supercede the FCOM)*	**FCOM Reference**
Warm-up	Standard Engine Start	At or near idle for at **least 2 minutes** before advancing the thrust lever to high power.	Standard Operating Procedure 3.03.09, SEQ 020, P1
Warm-up	Engine Start after prolonged shutdown period (more than 2 hours)	At or near idle for at **least 5 minutes** before advancing the thrust lever to high power (taxi time at idle may be included in the warm-up period).	Standard Operating Procedure 3.03.09, SEQ 030, P1 Supplementary Techniques 3.04.90, SEQ 030, P1
Cool-down	Engine Shutdown following high thrust operation (such as maximum reverse thrust during landing)	At idle for **3 minutes** prior to shutdown (can include operating time at idle, such as taxiing). Engine may be shut down after a 1 minute cooling period if demanded by operational requirements.	Standard Operating Procedure 3.03.25, SEQ 020, P1
Cool-down	Engine Shutdown after operation at power level above normal taxi maneuvering power or operation above reverse idle thrust.	At idle for **3 minutes** prior to shutdown.	Standard Operating Procedure 3.03.25, SEQ 050, P1

Figure 4.7
Overview of Engine Warm-up and Cool-down times (reference only)

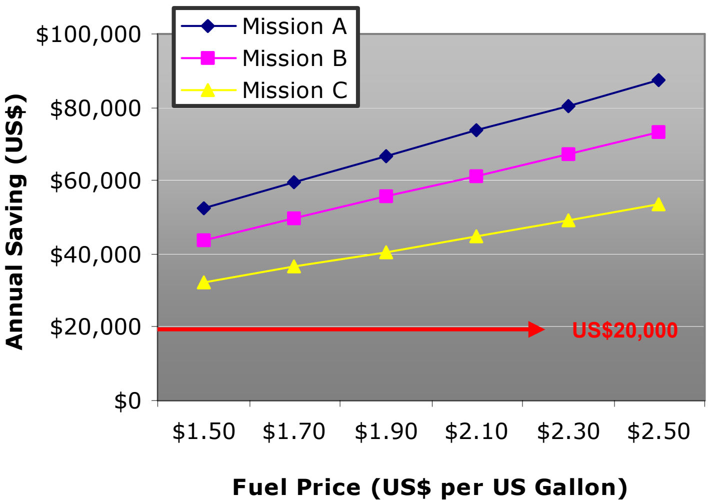
4.2.4.4 SINGLE ENGINE TAXIING

At large or busy airports where the taxi time to and from the runway can often exceed 15 minutes single engine taxi can bring considerable benefits.

> **Reference documents**
> Getting to Grips with Fuel Economy – Issue 4 October 2004
> FCOM Volume 3
> Point of contact: fltops.perfo@airbus.com

However, there are various factors that need to be considered before such a policy is implemented:

- Engine start-up, warm up and cool down times must be respected.
- Not suitable for high gross weights, uphill slopes or slippery runways.
- Not suitable for crowded ramps: due to reduction in aircraft maneuverability.
- Increased thrust setting on operational engine may increase ingestion of dust particles: refer to following section.
- Mechanical problems may only become apparent after gate departure.
- On landing APU can be started before engine shutdown: avoids electrical transients and allows galley operation.
- May increase tire wear and block time, but can reduce brake wear: through reduction in taxi speed.



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Fuel saved per sector (KGs):	**58**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Fuel saved per sector (KGs):	**58**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Fuel saved per sector (KGs):	**58**

Figure 4-8
Single engine taxiing for 10 minutes per flight

As with reduced use of the APU this initiative can be used to reduce CO_2 production in and around the airport terminal area. In the example shown above (single engine taxi for 10 minutes) CO_2 production would be reduced by around 180KGs (refer to the text box "Focus on CO_2" on page 10 for additional information).

4.2.4.5 HIGH POWER OPERATION AT LOW AIRCRAFT SPEEDS

Operating an engine at high power whilst the aircraft is stationary or taxiing at low speed increases suction and the likelihood of ingesting:

- Particles that will erode airfoils or block High Pressure Turbine (HPT) blade cooling holes,
- Foreign objects that could cause aerofoil damage.

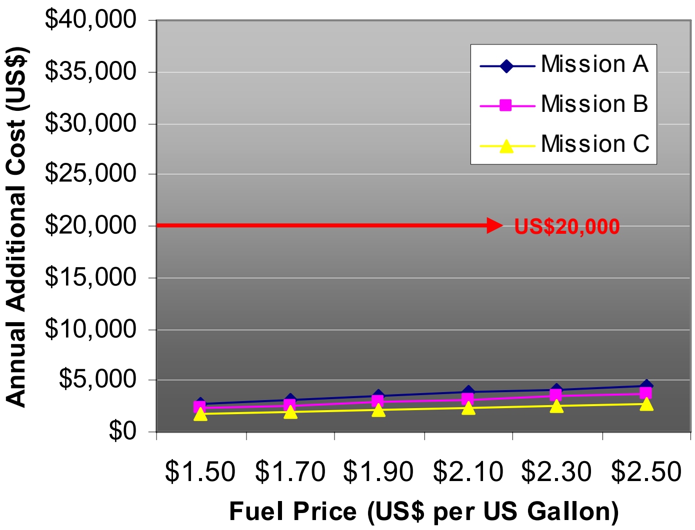
Once again these effects will lead to losses in engine efficiency and increase in fuel consumption. To minimize these effects the following measures should be considered:

- Early de-selection of MAX reverse thrust to IDLE reverse (refer also to Thrust Reverse section on page 28),
- Avoiding high thrust excursions during taxi,
- Progressive thrust increase with ground speed during take-off procedure.

Point of contact:
fltops.perfo@airbus.com

4.2.4.6 BLEED AIR USE

Use of the Environmental Control System (ECS) will increase engine or APU fuel consumption. Air for the ECS packs is taken, or bled, directly from the engine or APU compressors. Generation of this additional hot, compressed air requires more work to be done by the engines or APU and to achieve this, more fuel must be burnt.



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Fuel saved per sector (KGs):	**3**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Fuel saved per sector (KGs):	**3**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Fuel saved per sector (KGs):	**3**

Figure 4-9
Take-off without bleed

Take-off without bleed can reduce fuel consumption or allow take-off thrust to be optimized. When assessing this option, the actual cabin temperature and its effect on passenger comfort should be considered. The packs would be selected ON during the initial climb.

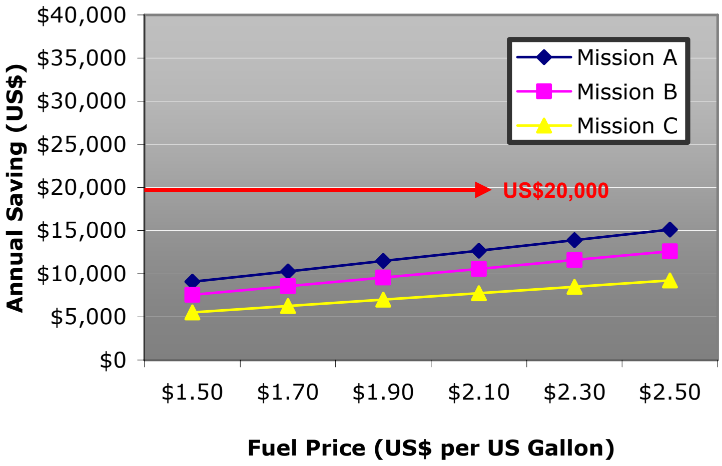
Reference documents
Getting to Grips with Fuel Economy – Issue 4 October 2004
Getting to Grips with Aircraft Performance – Issue 1 January 2002
Points of contact:
Aircraft performance: fltops.perfo@airbus.com
Passenger comfort: gilles.juan@airbus.com

The economic mode (select "LO" or "ECON" Pack Flow) reduces pack flow rate by 25% (with an equivalent reduction in the amount of air taken from the engines). This mode can be used on flights with reduced load factors and may be considered with higher load factors. In either case temperature variations within the cabin may develop but these can be minimized by cycling between economic and normal modes during the flight. Single pack operation is generally not recommended.

4.2.4.7 TAKE-OFF FLAP SETTING

The lowest flap setting for a given departure will produce the least drag and so give the lowest fuel burn, lowest noise and best flight profile. However other priorities such as maximizing take-off weight, maximizing flex temperature, maximizing passenger comfort, minimizing take-off speeds, etc… will often require higher flap settings. The most appropriate flap setting should be selected for each departure rather than systematic use of Config 3.

Reference documents
Getting to Grips with Fuel Economy – Issue 4 October 2004
Getting to Grips with Aircraft Performance – Issue 1 January 2002
Point of contact: fltops.perfo@airbus.com



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Fuel saved per sector (KGs):	**10**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Fuel saved per sector (KGs):	**10**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Fuel saved per sector (KGs):	**10**

Figure 4-10
Take-off with Config 1+F compared with Config 3

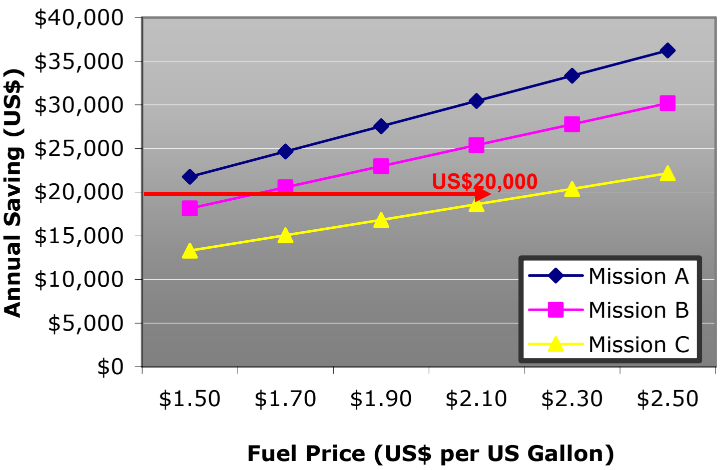
4.2.4.8 DEPARTURE DIRECTION

Ideally departure should be in direction of the flight. Most airports have Standard Instrument Departure (SID) routes that ensure terrain clearance or noise abatement requirements are met. The principle departure route will usually be the least demanding in terms of aircraft performance. Certain combinations of destination/wind direction/departure direction can lead to a departure route that adds several miles to the flight distance. At many airports alternate departure routes are available, when conditions allow, but their use may require a greater climb performance. In such circumstances the use of alternate departure routes should be assessed.

Point of contact: fltops.perfo@airbus.com

4.2.4.9 TAKE-OFF ACCELERATION ALTITUDE

The aircraft's climb to its cruising altitude is typically achieved in three basic steps. Following take-off, the aircraft will climb to what is known as the "acceleration altitude". Once at acceleration altitude, the aircraft's climb rate is temporarily reduced while its speed is increased to the optimum climb speed (known as the "green dot" speed). Once this speed is reached, the climb rate is increased so that the chosen cruising altitude can be achieved quickly and efficiently.



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Fuel saved per sector (KGs):	**24**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Fuel saved per sector (KGs):	**24**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Fuel saved per sector (KGs):	**24**

Figure 4-11
Using 800 Ft acceleration altitude instead of 1500 Ft

A low acceleration altitude will minimize fuel burn because arrival at the acceleration altitude also implies that the flaps and slats are retracted. These devices are used to optimize the initial climb but they have the effect of increasing drag, so, the earlier they are retracted the sooner the aircraft enters a more efficient aerodynamic configuration. However, ATC constraints or noise abatement requirements may often preclude the use of a lower acceleration altitude.

Reference documents
Getting to Grips with Fuel Economy – Issue 4 October 2004
Getting to Grips with Aircraft Performance – Issue 1 January 2002
Point of contact: fltops.perfo@airbus.com

4.2.4.10 APPROACH PROCEDURES

A number of fuel saving measures should be considered for the aircraft's approach:

- The aircraft should be kept in an aerodynamically clean configuration as long as possible with landing gear and flaps only being deployed at the required moment.
- A continuous descent will minimize the time the aircraft spends at a non-optimum altitude, and projects to study how this can be achieved with increased regularity within a congested air traffic environment are underway.

- Visual approaches should be considered, as airport instrument approach paths do not always offer the most direct route to the runway.

Reference documents
Getting to Grips with Fuel Economy – Issue 4 October 2004
Point of contact: fltops.perfo@airbus.com

4.2.4.11 LANDING FLAP CONFIGURATION

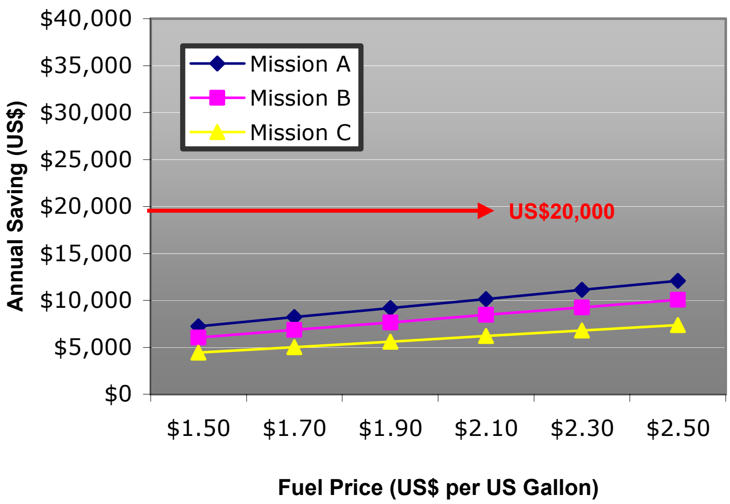
Conf 3, where conditions enable its use, will allow fuel to be saved because it is more aerodynamically efficient than the more typically used FULL configuration (Note: CAT 2/3 low visibility landings nominally require Conf FULL).

However, the following operational and economic aspects should be considered for each landing:

Reference documents
Getting to Grips with Fuel Economy – Issue 4 October 2004
Getting to Grips with Aircraft Performance – Issue 1 January 2002
Point of contact: fltops.perfo@airbus.com

- Aircraft landing weight
- Runway length available
- Suitability of low or med automatic braking: reduced deceleration, increased landing distance.
- Preferred runway exit point: potential increase in runway occupancy time and block time.
- Runway surface conditions: effect on brake efficiency.
- Tailwinds: effect on landing ground speed and distance.
- Additional brake cooling time: increase in turn around time.
- Potential increase in brake and tire wear.
- Risk of exceeding maximum brake temperature and subsequently damaging brakes.

Important Notice
In order to maximize safety margins the Airbus FCOM (Flight Crew Operating Manual) recommends the use of the FULL configuration for all landings. Nonetheless, where runway length and conditions are favorable configuration 3 may be considered.



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Fuel saved per sector (KGs):	**8**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Fuel saved per sector (KGs):	**8**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Fuel saved per sector (KGs):	**8**

Figure 4-12
Landing in Conf 3 instead of Conf Full

Focus on Balancing Costs
Sections 4.2.4.11 and 4.2.4.12 (Landing Flap Configuration and Reverse Thrust) both discuss initiatives that can bring worthwhile fuel savings. However, the potential cost of achieving these savings should not be ignored.

A normal consequence of applying either of the referenced initiatives will be an increase in landing distance. An increase in landing distance could mean that the normal runway exit cannot be used and possibly increase the block time for the flight. For many airlines an increase in block time will mean an increase in flight crew pay for the flight in question. This additional cost must be weighed against the saving made in fuel cost.

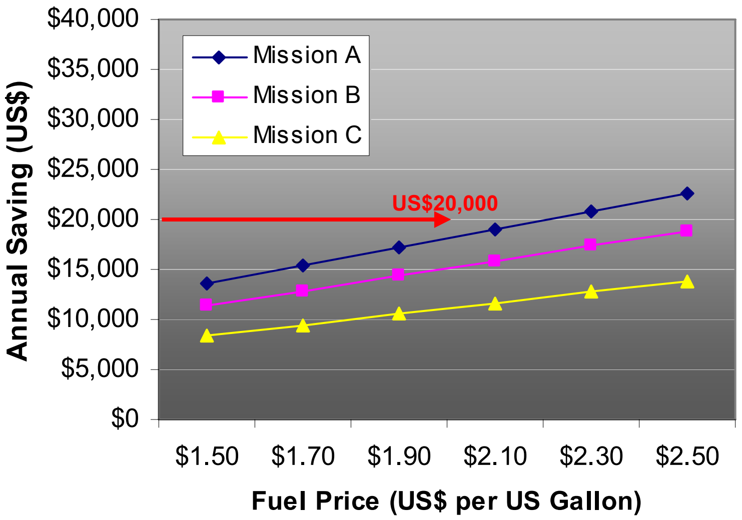
In some circumstances the landing distance increase mentioned above may be limited by greater use of the brakes. This may allow the preferred runway exit to be used and thus allow block times to be maintained. However, an increase in brake use may also bring an increase in brake and tire wear. This increase in wear would usually be expected to increase the "per landing" cost of these components and, once again, the additional cost must be weighed against the saving made in fuel cost.

4.2.4.12 REVERSE THRUST

Using idle reverse on landing instead of full reverse will reduce fuel consumption and may benefit the engine.

Reference documents
Getting to Grips with Aircraft Performance – Issue 1 January 2002
Point of contact: fltops.perfo@airbus.com

However, the aircraft's kinetic energy at landing must still be dissipated. It may be possible to achieve this over a longer landing distance and thereby limit any increases in brake and tire wear this procedure implies but, in all cases, the operational and economic aspects highlighted in the previous section (Landing Flap Configuration) should be considered for each landing (refer to Focus on Balancing Costs text box (above) for further details).



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Fuel saved per sector (KGs):	**15**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Fuel saved per sector (KGs):	**15**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Fuel saved per sector (KGs):	**15**

Figure 4-13
Using reverse idle instead of reverse max

Important Notice

In order to maximize safety margins the Airbus FCOM (Flight Crew Operating Manual) recommends the use of maximum thrust reverse for all landings. Nonetheless, where runway length and conditions are favorable reverse idle may be considered.

In concluding this section we review a couple of items that may be erroneously associated with fuel efficiency.

4.2.4.13 CENTER OF GRAVITY

All commercial aircraft must have their center of gravity (CG) forward of their center of lift in order to remain stable in flight. Fuel and payload disposition determines the CG position and the allowable range of CG positions is defined in the Flight Manual. On many aircraft a CG position towards the rear of the allowable range will allow a more aerodynamic configuration. However, for aircraft of the A320 Family CG position has a negligible effect on fuel consumption.

4.2.4.14 TAKE-OFF THRUST REDUCTION

A reduction in engine thrust during the take-off phase will reduce fuel flow. Reduced thrust implies reduced performance and will mean that the aircraft takes longer to achieve its optimum climb and cruise configurations. As a result, the use of reduced thrust using either de-rate or the flex (flexible) take-off technique will often increase overall fuel consumption. However, even in today’s environment of elevated fuel prices, this is more than compensated for by the reduction in engine stress and wear and consequent reduction in maintenance cost that thrust reduction offers.

AIRCRAFT PROCEDURE FUEL CONSERVATION ACTION OVERVIEW

The following actions for operational cost reduction have been described in the preceding sections:

- Use of fuel tankering,
- Minimizing use of APU,
- Adherence to minimum engine warm-up and cool-down periods,
- Single engine taxi,
- Use of reduced take-off thrust reduction,
- Use of high engine power settings at low speed,
- Minimizing bleed air use,
- Departure route assessment,
- Take-off flap setting,
- Take-off acceleration altitude reduction,
- Approach procedure review,
- Landing flap configuration,
- Use of reduced thrust reverse.

4.3 MAINTENANCE INITIATIVES

In this section, the value of careful aircraft maintenance is considered. Proactive measures include regular inspections and repair, when necessary. Before that is reviewed, the following section covers a document that allows aircraft operations when specified components have failed. Its content is usually considered as being the responsibility of both the operational and maintenance domains.

4.3.1 IMPLICATIONS OF DISPATCHING UNDER MEL AND CDL

Operators are provided with a Master Minimum Equipment List (MMEL) that is the basis for their MEL (Minimum Equipment List). The MEL is a valuable tool for optimizing dispatch reliability because it defines the conditions under which the aircraft may be dispatched with specified equipment inoperative.
The conditions include the period during which the aircraft can be operated with the system inoperative and, in some cases, requirements for additional fuel load.
The Configuration Deviation List (CDL) in chapter 6 of the Flight Manual (FM) also allows the aircraft to be dispatched with specified components not fitted. All components must be re-installed at the earliest maintenance opportunity (nominally within 1 week, subject to local airworthiness authority approval).

Points of contact:
MMEL content: fltops.mmel@airbus.com
CDL (FM) content: fltops.afm@airbus.com
Aircraft performance: fltops.perfo@airbus.com

For items whose loss or failure will bring a fuel consumption penalty, it is beneficial to make special efforts to replace them as soon as possible.

The tables on the following page indicate the MMEL and CDL items that will have a noticeable negative impact on fuel cost. They indicate the penalty for typical sector lengths and also the cost of the additional fuel (calculated at a fixed price of US$2.00 per US Gallon) that would be burnt during the nominal period allowed for repairs (10 days for MMEL item and 1 week for a CDL item). The typical missions, used throughout this document, are defined in the adjacent table.

Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3

System/ Component	MMEL Condition	Maximum additional fuel required per sector - Kilograms *(Cost of additional fuel over 10 days - at US$2.00 / US gallon)*		
		Mission A (1.5 hours)	Mission B (2 hours)	Mission C (3 hours)
AC Main generation unavailable (IDG, GCU, line contactor) *MMEL 24-10-01*	• APU operating throughout flight (max. flight level limited to 33500 feet) • 10 days to repair + a 10 day extension*	168 KGs *(US$5,500)*	246 KGs *(US$6,800)*	253 KGs *(US$5,100)*
Engine Anti-Ice Valve failed in open position *MMEL 30-21-01*	• 10 days to repair + a 10 day extension*	72 to 144 KGs (depending on engine type) *(US$2,400 to US$4,750)*	94 to 189 KGs (depending on engine type *(US$2,600 to US$5,200)*	140 to 281 KGs (depending on engine type *(US$2,850 to US$5,700)*
Right-hand Wing Anti-Ice Valve failed in open position *MMEL 30-11-01*	• 10 days to repair + a 10 day extension* • Left-hand Wing Anti-ice Valve failed in open position is NO-GO	47 KGs *(US$1,550)*	61 KGs *(US$1,600)*	91 KGs *(US$1,850)*
Landing Light failed in extended position *MMEL 33-40-02*	• 10 days to repair + a 10 day extension*	36 KGs *(US$1,200)*	47 KGs *(US$1,300)*	70 KGs *(US$1,400)*

*As per the JAR-MMEL/MEL (subject to the approval of the National Aviation Authority)

Figure 4-14
Performance Related MMEL items
Additional fuel used when operating under specific MMEL
(over a 10 day period)

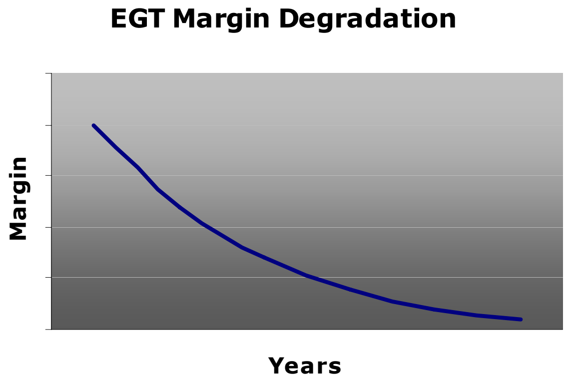
CDL Item	Maximum additional fuel required per sector – Kilograms *(Cost of additional fuel over 7 days - at US$2.00/ US gallon)*		
	Mission A (1.5 Hours)	Mission B (2 Hours)	Mission C (3 Hours)
Thrust reverser blocker doors	11 KGs *(US$260)*	14 KGs *(US$270)*	21 KGs *(US$300)*
Ram air inlet or outlet flaps	18 KGs *(US$420)*	24 KGs *(US$470)*	35 KGs *(US$500)*
Wing tip fence: lower part	25 KGs *(US$580)*	33 KGs *(US$640)*	49 KGs *(US$700)*
Wing tip fence: complete fence	50 KGs *(US$1,160)*	66 KGs *(US$1,280)*	98 KGs *(US$1,390)*
Flap track fairing 1A extension Flaps track fairing	108 KGs *(US$2,510)*	141 KGs *(US$2,730)*	211 KGs *(US$3,000)*

Figure 4-15
Additional fuel used when operating under specific CDL conditions
(over a 7 day period)

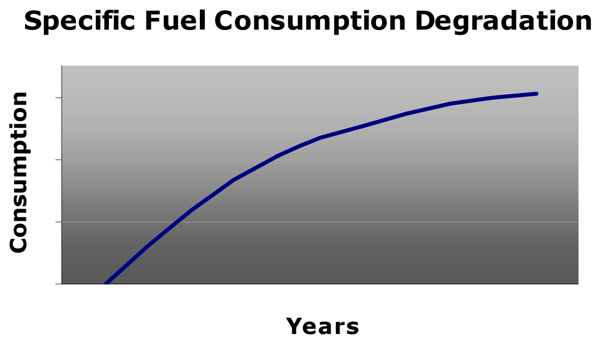
4.3.2 PROPULSION SYSTEMS MAINTENANCE

During normal operations all engines will experience rubbing, thermal stress, mechanical stress, dirt accumulation, foreign object ingestion and so on. These effects will eventually result in a measurable decrease in performance. Typical indicators of engine performance are:

- Exhaust Gas Temperature (EGT) increase: as engine efficiency decreases, more fuel is required to achieve a given thrust. An increase in fuel required will typically produce an increase in EGT. Monitoring EGT margin (see note [1] below) at take-off is a good indicator of engine deterioration. This can easily be done using data recorded during the flight that is subsequently processed on the ground by engine health monitoring software.



- Specific Fuel Consumption (SFC) also typically increases as engine efficiency falls (again, due to the need for more fuel to achieve a given thrust). This SFC degradation has a direct impact on aircraft performance in terms of Specific Range and thus on the fuel burn for a given mission.



The rate of degradation of these parameters is highly dependent on the rate at which the aircraft accumulates flight hours and cycles and the environments in which it operates.

The progressive increase in both fuel consumption and CO_2 production (refer to "Focus on CO_2" text box on page 10) must be balanced against the significant costs that will be incurred when the engine is eventually removed from the aircraft for overhaul. The moment of the engine's overhaul may be postponed through careful maintenance of the engine while it remains on wing.

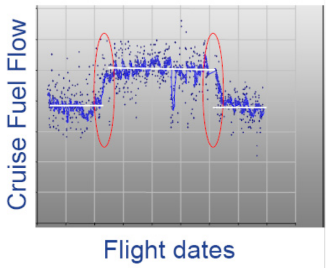
[1] EGT Margin: the difference between actual EGT and the maximum EGT that can be tolerated by the engine. Once this maximum temperature is reached the engine must be removed for maintenance and consequent restoration of EGT margin.

When the time to remove the engine arrives, the extent and cost of the overhaul and refurbishment must be carefully balanced against the improvements in EGT margin and fuel consumption it will bring. These aspects should be carefully assessed and regularly reviewed with the engine manufacturer, engine overhaul shop and, or by using the services of one of the many third party engine support companies.

4.3.2.1 TREND MONITORING

Routine monitoring of engine and aircraft performance using the software tool provided by the engine manufacturer and Airbus' Aircraft Performance Monitoring software (refer to "PEP" text box on page 16) will allow long-term performance degradation discussed above to be assessed and permit detection of unexpected shifts in engine/aircraft performance. Timely detection can provide advanced warning of a possible failure. The identification and launching of appropriate maintenance actions will reduce the risk of an operational event and minimize any additional fuel consumption associated with the problem.

Engine Manufacturer Web Sites:
http://www.cfm56.com/
http://www.iae4u.com/



4.3.2.2 ROUTINE ENGINE MAINTENANCE

The following maintenance initiatives should be considered for all operations.

Engine wash

With time, dirt will accumulate on the engine's fan and compressor airfoils and consequently reduce engine efficiency. Water washes of the engine fan and core are recommended to remove this and can often reduce fuel flow by 0.5% and up to 1% - representing an annual fuel cost saving per aircraft typically from US$24,100 and up to US$51,700 (with fuel at US$2.00 per US gallon and depending on the mission). Periodic engine water washes also have a positive effect on the exhaust gas temperature margin and consequently on engine overhaul intervals.

Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3

Contamination levels depend on the aircraft's operation and environment, so each operator must optimize their wash frequency. As a starting point, operators are advised to carry out engine washes once a year. Operators wishing to optimize wash frequency may do so by monitoring the effects against and appropriate control data set (e.g. previously accumulated data or a partial fleet at the previous wash frequency).

Reference document
AMM procedure: 72.00.00 PB701

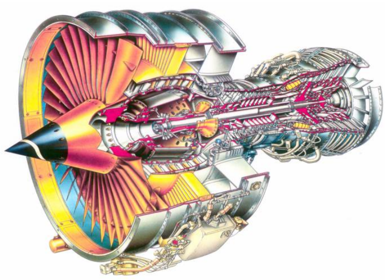
Engine wash Potential fuel economy per sector (Kilograms)		
Mission A (1.5 Hours)	Mission B (2 Hours)	Mission C (3 Hours)
20 to 35 KGs	25 to 50 KGs	35 to 70 KGs

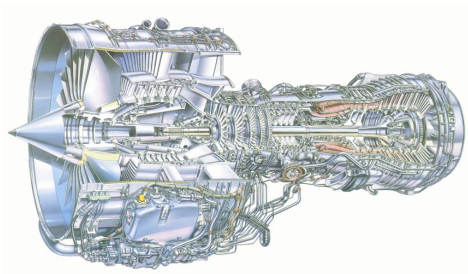
Figure 4-16
Potential benefits of Engine wash on fuel consumption

Check of thrust reverser seal condition

The clean passage air through the engine nacelles (known as the by-pass air) is essential to overall engine efficiency. Seals around the thrust reversers play a crucial role in ensuring that this occurs and that overboard leakage is avoided.

Reference documents
AMM procedure:
CFM: 78-11-11 PB601
78-32-41 PB601
IAE: 78-11-11 PB601
78-32-79 PB601





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4.3.3 AIRFRAME MAINTENANCE

The airframe is a complex shape and includes many panels, doors and flight control surfaces. In order for the aircraft to perform at its optimum efficiency (i.e. to create the lowest amount of drag), the airframe must be as free from irregularities as possible. This means that surfaces should be as smooth as possible, panels and doors should be flush with surrounding structure and all control surfaces should be rigged to their specified positions.

Deterioration of the aircraft's external surface is a normal consequence of its use. Like all modern commercial aircraft, those of the A320 Family must be maintained in accordance with the approved maintenance schedule. One objective of the maintenance schedule is to preserve aircraft's operational efficiency by the most economic means possible. This is achieved through inspection, and subsequent repair as necessary, in specified areas at specified intervals. These intervals are the minimum allowable and the industry is constantly seeking to extend all task intervals. Carrying out any maintenance task more regularly will inevitably increase maintenance costs. However, in this section we consider tasks that can bring considerable reductions in fuel consumption when the need for repair is discovered.

4.3.3.1 GENERAL

Reference documents
Getting Hands-on Experience with Aerodynamic Deterioration – issue 2, October 2001
SRM 51-10-00 PB001

In terms of overall airframe condition (dents, panel gaps, under or over filled panel joints, etc…) particular attention should be paid to areas of the airframe that air impinges on first (e.g. forward portion of the fuselage, the nacelles, the wings, the fin, etc). These areas are defined more clearly in the document referenced in the adjacent text box. The document also contains a detailed assessment of all areas where aerodynamic deterioration may occur.

Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3

The following sections highlight airframe problems that are both typical in-service and have a particularly negative impact on aerodynamic performance. In each case, the problem is presented in terms of additional fuel burnt per sector (for the selection of typical missions shown in the adjacent text box), and this is also expressed in terms of additional fuel cost per **month** (charts showing cost per year are presented earlier in this document). Once again, in the interests of clarity two different cost axis scales are used. To highlight the variations in cost axis scale, a fixed cost reference line has been added to each chart. Given that these charts show monthly figures the reference cost is US$5,000 (US$5,000).

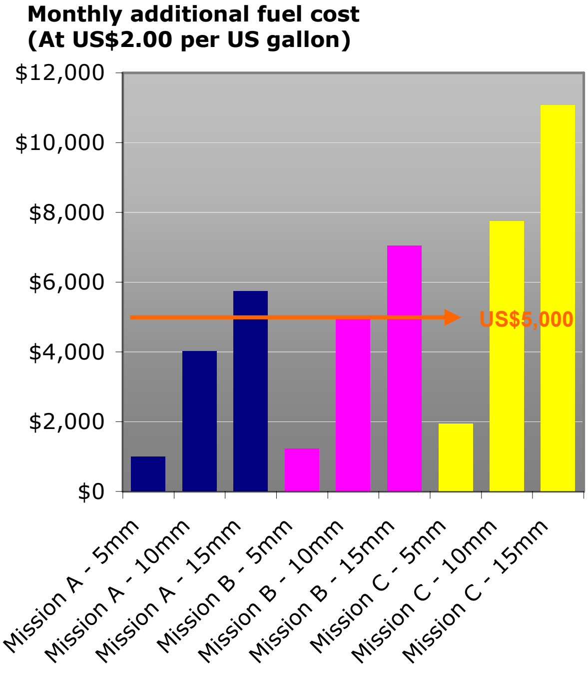
Unlike the operational issues described earlier in this document, the effect of the contributors to aerodynamic deterioration varies quite significantly with aircraft type.

Percentage variation from A320 - all defects	A318	A319	A320	A321
Mission A	**-26%**	**-11%**	**0%**	**5%**
Mission B	**-19%**	**-5%**	**0%**	**14%**
Mission C	**-27%**	**-7%**	**0%**	**10%**

Each of the effects presented in this document are described in the context of the A320. For the A318, A319 and A321 the factors in the above table should be applied to the additional fuel used and additional fuel cost figures shown.

4.3.3.2 FLIGHT CONTROLS

Correct rigging of all flight control surfaces is important to aerodynamic efficiency, however, of particular importance are the slats on the wing leading edge and the spoilers on the upper surface. These flight controls are only occasionally deployed during the flight, but are fitted to areas of the wing that are particularly sensitive to imperfections. Such imperfections occur when a slat or spoiler is not flush with the wing profile. The effect on aircraft performance varies with the size of the gap or "mis-rig". To illustrate this, the effect of a slat or spoiler mis-rigged either by 5, 10 and 15 millimeters is presented for each mission profile (at a fixed fuel price).

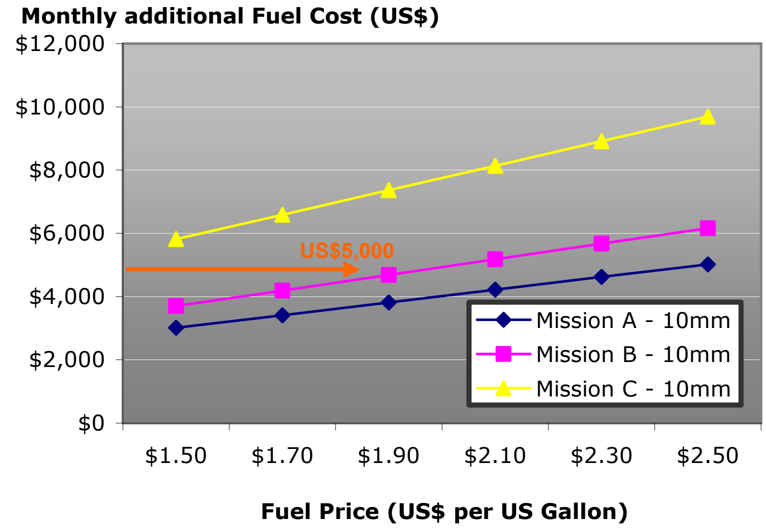


		Slat Mis-Rig		
Data - Mission A		5mm	10mm	15mm
Annual cycles:	1800			
Annual Flight Hours:	2700			
Average sector length (Hours):	1.5			
Additional fuel per sector - A320* (KGs):		7	27	38
Data - Mission B				
Annual cycles:	1500			
Annual Flight Hours:	3000			
Average sector length (Hours):	2			
Additional fuel per sector - A320* (KGs):		7	29	42
Data - Mission C				
Annual cycles:	1100			
Annual Flight Hours:	3300			
Average sector length (Hours):	3			
Additional fuel per sector - A320* (KGs):		11	42	60

*Figures represent additional fuel burn and cost for an A320 aircraft. For A318, A319 and A321 the factors shown in the table at the top of the page should be applied.

Figure 4-17
Slat mis-rig of 5,10 and 15 mm (A320* - fixed fuel price)

Now, considering a only slat mis-rig of 10mm but looking at how varying fuel price will affect the additional fuel expenditure.

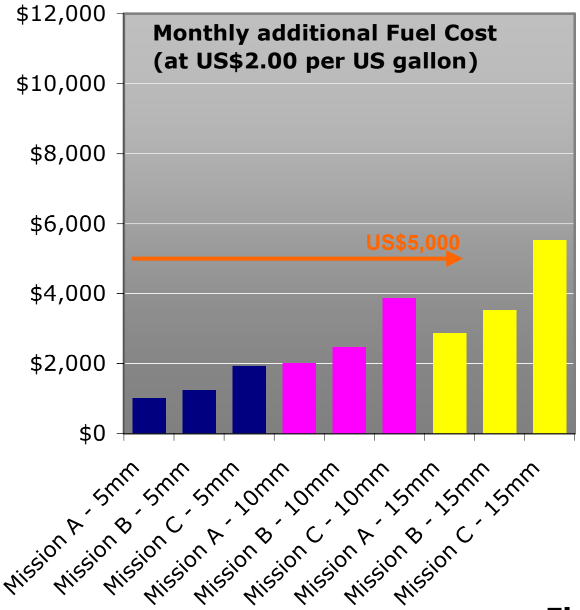


References: Slat Mis-rig

MPD Task Reference:	ZL-500-02-1
Estimated inspection time (all slats):	40 minutes plus access time
MPD Task Interval:	C-check (every 20 months or 6000 flight hours)
Estimated rigging time for one slat:	4 man-hours
AMM Reference:	27-84-63/64/65/66/67 PB401

Figure 4-18
Slat mis-rig of 10 mm (A320* - variable fuel price)

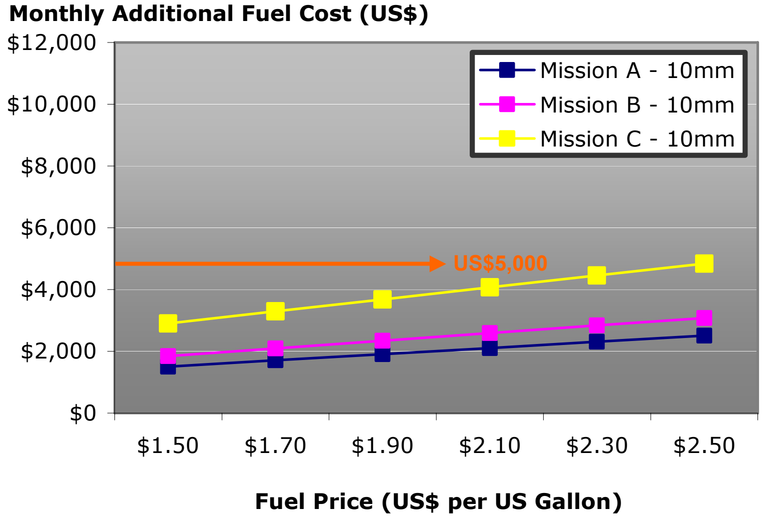
And now the same two charts, but this time considering the impact of a mis-rigged spoiler.



		Spoiler Mis-Rig		
Data - Mission A		5mm	10mm	15mm
Annual cycles:	1800			
Annual Flight Hours:	2700			
Average sector length (Hours):	1.5			
Additional fuel per sector - A320* (KGs):		7	13	19
Data - Mission B				
Annual cycles:	1500			
Annual Flight Hours:	3000			
Average sector length (Hours):	2			
Additional fuel per sector - A320* (KGs):		7	15	21
Data - Mission C				
Annual cycles:	1100			
Annual Flight Hours:	3300			
Average sector length (Hours):	3			
Additional fuel per sector - A320* (KGs):		11	21	30

*Figures represent additional fuel burn and cost for an A320 aircraft. For A318, A319 and A321 the factors shown on page 37 should be applied.

Figure 4-19
Spoiler mis – rig of 5, 10 and 15 mm (A320* fixed fuel price)



References: Spoiler Mis-rig

MPD Task Reference:	276400-02-1
MPD Task Interval:	18000 flight hours
Estimated inspection time (all spoilers):	3 hours plus access time
Estimated rigging time for one spoiler:	8 man-hours
AMM Reference:	27-64-00 PB501

Figure 4-20
Spoiler mis – rig of 10 mm (A320* variable fuel price)

How to interpret the charts

Example: additional cost of fuel per month caused by one spoiler mis-rigged by 10mm and assuming fuel is US$2.00 per US gallon.

For A320 (consult figure 4-20 directly):

- Additional fuel per month: between about US$2,000 (mission A type operation) and US$3,900 (mission C type operation).

For A318 (consult figure 4-20 and then apply the factors shown in table at top of page 37):

- Additional fuel per month: between about US$1,480 (-26% of mission A figure for A320) and US$2,850 (-27% of mission C figure for A320).

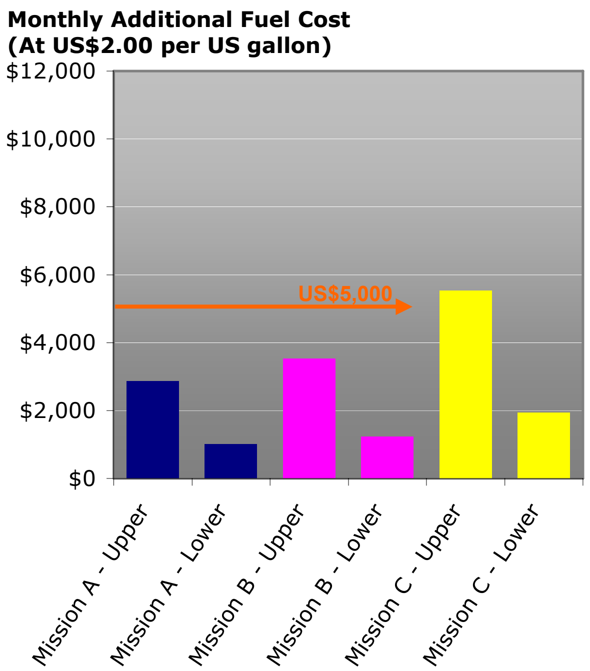
For both types around 11 man-hours would be required to inspect all spoilers and repair one (labour costs around US$900 to US$1,600). The standard inspection interval is every 60 months.

Consulting figure 4-19 allows an assessment of effect of increased or reduced mis-rig to be made.

4.3.3.3 WING ROOT FAIRING PANEL SEALS

The aircraft exterior transitions between the wing root and the fuselage via a number of fairing panels. These panels are not part of the aircraft's primary structure but they perform an important role in managing the airflow in this aerodynamically critical area. Flexible seals, which are sometimes referred to as "Karman seals", cover gaps between the panels and the adjacent wing or fuselage structure.

The following quantifies the effect of the loss of any seal above (upper) or below (lower) the wing.



		Missing Karman Seal Upper	Missing Karman Seal Lower
Data - Mission A			
Annual cycles:	1800		
Annual Flight Hours:	2700		
Average sector length (Hours):	1.5		
Additional fuel per sector - A320* (KGs):		19	7
Data - Mission B			
Annual cycles:	1500		
Annual Flight Hours:	3000		
Average sector length (Hours):	2		
Additional fuel per sector - A320* (KGs):		21	7
Data - Mission C			
Annual cycles:	1100		
Annual Flight Hours:	3300		
Average sector length (Hours):	3		
Additional fuel per sector - A320* (KGs):		30	11

*Figures represent additional fuel burn and cost for an A320 aircraft.
For A318, A319 and A321 the factors shown on page 37 should be applied.

Figure 4-21
Missing Wing Root Fairing Seals
Upper and Lower Seals (A320* - fixed fuel price)

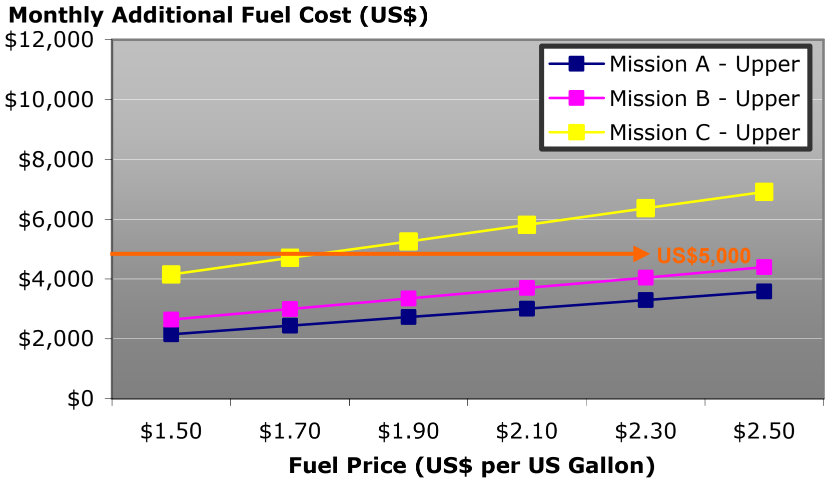


Figure 4-22
Missing Upper Wing Root Fairing Seals (A320* - variable fuel price)

References: Missing Karman Seals	
MPD Task Reference:	ZL-100-02-1
MPD Task Interval:	every 100 days
Estimated inspection time:	15 minutes
Estimated time to replace one seal:	2 man-hours
AMM Reference:	53-35-11 PB401

4.3.3.4 MOVING SURFACE SEALS

Gaps between the various sections of the aircraft's structure can disrupt local airflow and this will generate unnecessary drag, and have a consequent impact on fuel consumption. Flexible seals are often used to fill external gaps between moving surfaces and access panels and their surrounding structure.

The effect on fuel consumption of moving surface seals that are often found missing or damaged in-service and have a particularly negative impact on aerodynamic performance are highlighted here.

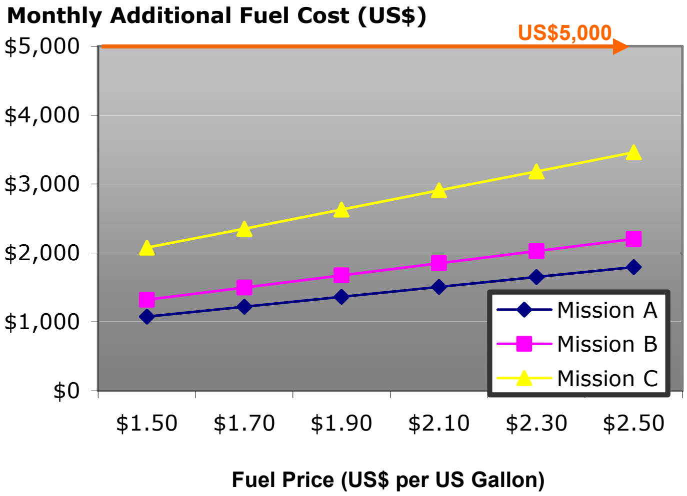
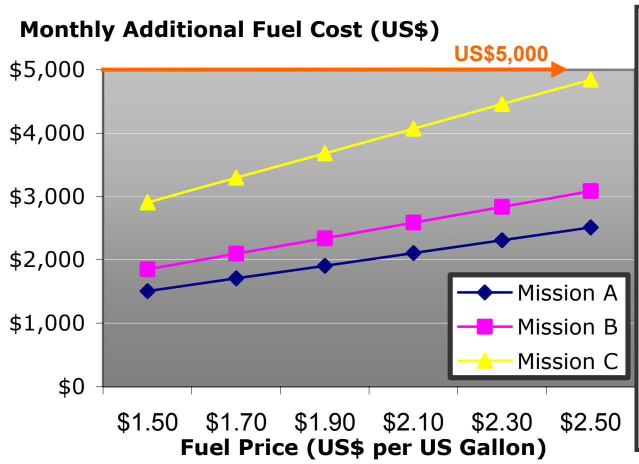


Figure 4-23
Missing seal: slat – spanwise (A320*)

Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Additional fuel per sector - A320* (KGs):	**10**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Additional fuel per sector - A320* (KGs):	**11**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Additional fuel per sector - A320* (KGs):	**15**

*Figures represent additional fuel burn and cost for an A320 aircraft.
For A318, A319 and A321 the factors shown on page 37 should be applied.

References: Missing seal - slat (spanwise)	
MPD Task Reference:	ZL-500-02-1
MPD Task Interval:	every 20 months or 6000 flight hours
Estimated inspection time (all slats):	20 minutes
Estimated repair time per slat seal:	3 man-hours
AMM Reference:	57-40-00 PB401

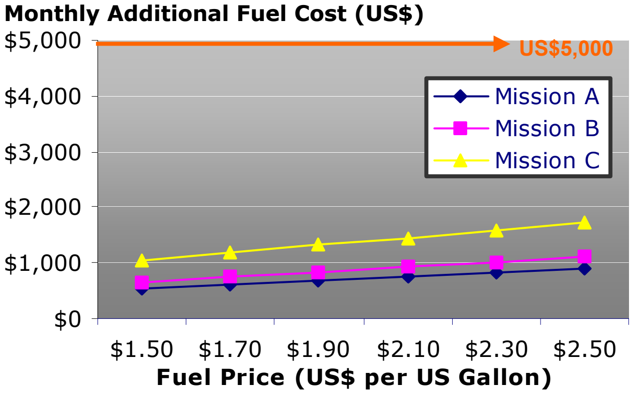


Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Additional fuel per sector - A320* (KGs):	**13**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Additional fuel per sector - A320* (KGs):	**15**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Additional fuel per sector - A320* (KGs):	**21**

*Figures represent additional fuel burn and cost for an A320 aircraft.
For A318, A319 and A321 the factors shown on page 37 should be applied.

Figure 4-24
Missing seal: spoiler and flap (junction and cordwise)
(and leaking passenger or cargo door seal)
(A320* - variable fuel price)

References: Missing seal - spoiler and flap (junction and cordwise)	
MPD Task Reference:	ZL-500-02-1
MPD Task Interval:	every 20 months or 6000 flight hours
Estimated inspection time (all spoilers):	15 minutes
Estimated repair time for one spoiler seal:	2 man-hours
AMM Reference:	27-64-41 thru 27-64-45 PB401
Estimated inspection time (all flap seals):	15 minutes
Estimated repair time per flap junction seal:	1,5 man-hours
AMM Reference:	27-54-61 PB401
Estimated repair time per flap cordwise seal:	1 man-hour
AMM Reference:	27-54-61 PB401



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Additional fuel per sector - A320* (KGs):	**5**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Additional fuel per sector - A320* (KGs):	**5**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Additional fuel per sector - A320* (KGs):	**8**

*Figures represent additional fuel burn and cost for an A320 aircraft.
For A318, A319 and A321 the factors shown on page 37 should be applied.

Figure 4-25
Missing seal: aileron - span and cordwise
(and nose landing gear door mis-rig of 10mm) (A320* - variable fuel price)

References: Missing seal: aileron - span and cordwise	
MPD Task Reference:	271400-02-2
MPD Task Interval:	every 60 months or 18000 flight hours
Estimated inspection time (both ailerons):	10 minutes
Estimated repair time for one cordwise seal:	1 man-hour
AMM Reference:	27-14-00
Estimated repair time for one spanwise seal:	1,5 man-hours
AMM Reference:	27-14-00

4.3.3.5 THRUST REVERSER SEALS

The importance of these seals to the clean passage of air inside the nacelle has already been mentioned. The nacelle exterior surface is another aerodynamically sensitive area so the turbulence resulting from the gap made by a missing seal will have a significant impact.

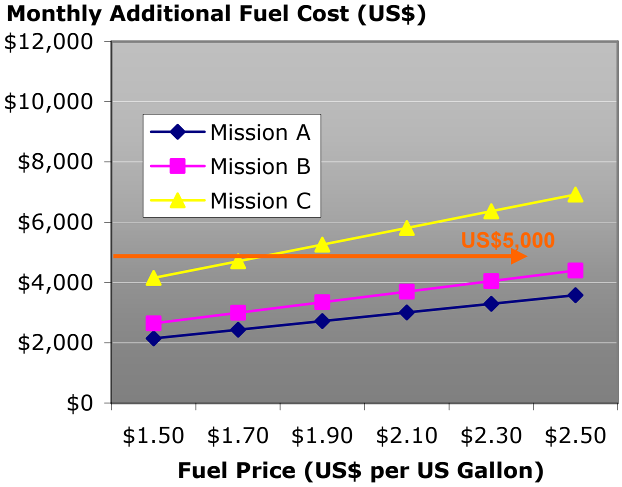


Figure 4-26
Thrust Reverser Seal Missing
(A320* - variable fuel price)

Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Additional fuel per sector - A320* (KGs):	**19**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Additional fuel per sector - A320* (KGs):	**21**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Additional fuel per sector - A320* (KGs):	**30**

*Figures represent additional fuel burn and cost for an A320 aircraft.
For A318, A319 and A321 the factors shown on page 37 should be applied.

References: Missing Thrust Reverser Seal	
MPD Task Reference:	ZL-451-01
MPD Task Interval:	every 400 days
Estimated inspection time (all doors):	15 minutes plus access time
Estimated seal replacement time:	20 man-hours
AMM Reference:	IAE 78-11-11 PB801
	IAE 78-32-76/79 PB801

4.3.3.6 LANDING GEAR DOORS

Mis-alignment or mis-rigging on any main or nose landing gear door will lead to unnecessary drag being generated.

The aerodynamic penalty and consequently the fuel burn penalty of a nose landing gear door mis-rig of 10 millimeters is similar to that for a missing aileron seal that is illustrated on page 43 (figure 4-25). The references are shown below:

References: Nose landing gear door mis-rig	
MPD Task Reference:	ZL-711-01-1
MPD Task Interval:	every 100 days
Estimated inspection time (all doors):	15 minutes (plus aircraft jacking for aft doors)
Estimated re-rig time:	24 man-hours
AMM Reference:	32-22-00 PB601

A similar mis-rig (10mm) on a main landing gear door has a slightly lower aerodynamic penalty because the aircraft is less sensitive to such problems at more aft positions. The additional fuel burn is presented below.

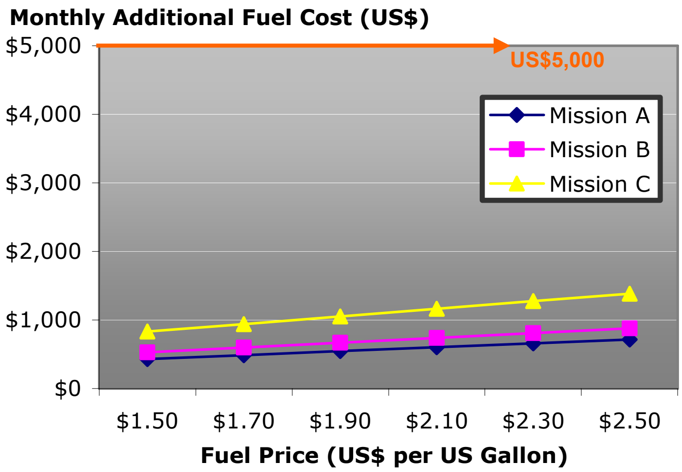


Figure 4-27
Main Landing Gear Door mis-rig of 10 mm (A320* - variable fuel price)

Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Additional fuel per sector - A320* (KGs):	**4**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Additional fuel per sector - A320* (KGs):	**4**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Additional fuel per sector - A320* (KGs):	**6**

*Figures represent additional fuel burn and cost for an A320 aircraft.
For A318, A319 and A321 the factors shown on page 37 should be applied.

References: Main landing gear door mis-rig	
MPD Task Reference:	ZL-733-01-1
MPD Task Interval:	every 100 days
Estimated inspection time (all doors):	15 minutes (plus aircraft jacking for fairings)
Estimated re-rig time:	20 man-hours
AMM Reference:	32-12-11/13/14 PB401

While inspecting the alignment of the landing gear doors, the opportunity to check the condition and effectiveness of their seals should also be taken.

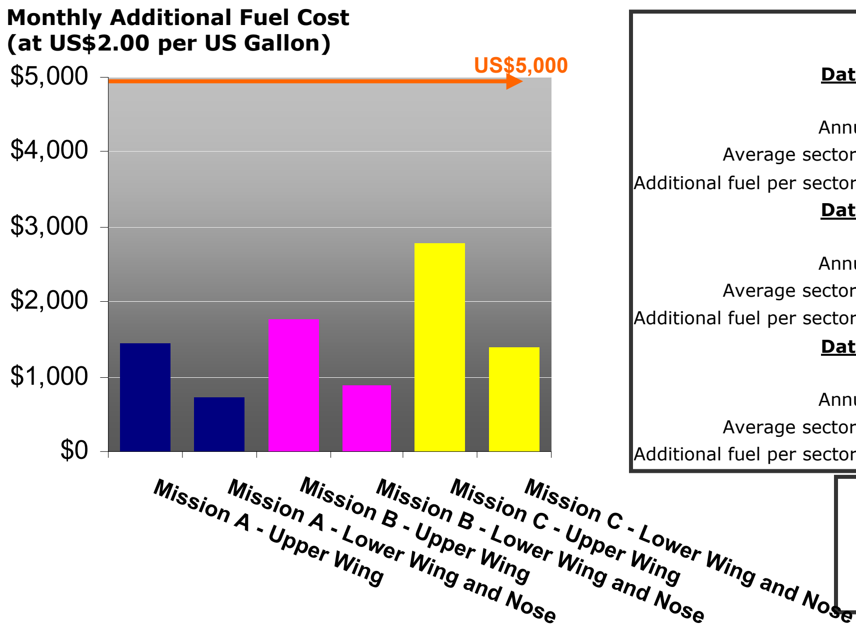
4.3.3.7 DOOR SEALS

The passenger and cargo bay door seals serve a dual function. These seals not only fill the gap between the door and its surrounding structure but they also render the door airtight. This allows the aircraft to be pressurized efficiently. A damaged, leaking seal allows pressurized cabin air to escape in a direction perpendicular to the fuselage skin. The effect on the local airflow can be quite significant. The actual resulting aerodynamic deterioration is similar to that seen when a flap or spoiler seal is missing so the fuel burn penalty can be seen on the charts on page 42 (figure 4-24). The references are shown below.

References: leaking passenger or cargo bay door seal	
MPD Task Reference (passenger doors):	ZL-831-01-1
MPD Task Reference (cargo doors):	ZL-825-01-1 and ZL-826-01-1
MPD Task Interval:	every 100 days
Estimated inspection time (all doors):	1 man-hour plus access
Estimated replacement time (pax door seal):	4 man-hours
AMM Reference:	Passenger Door Fwd: 52-11-18 PB 401 & Aft: 52-13-18 PB 401
Estimated replacement time (cargo door seal):	8 man-hours
AMM Reference:	Cargo Door Fwd 52-31-18 PB 401 & Aft: 52-32-18 PB 401

4.3.3.8 PAINT CONDITION

Deterioration of the aircraft's exterior surface is to be expected on any aircraft in service. The rate of deterioration can vary with the intensity of the utilization and environmental conditions. Although the thickness of paint is typically around 1/3 millimeter, its loss in critical areas of the airframe will upset the local airflow to an extent that overall drag can be increased. Particular attention should be paid to the nose and cockpit area and the wing upper and lower surfaces.



		Typical Paint Peeling		
		Upper Wing	Lower Wing	Nose
Data - Mission A				
Annual cycles:	1800			
Annual Flight Hours:	2700			
Average sector length (Hours):	1.5			
Additional fuel per sector - A320* (KGs):		10	5	5
Data - Mission B				
Annual cycles:	1500			
Annual Flight Hours:	3000			
Average sector length (Hours):	2			
Additional fuel per sector - A320* (KGs):		11	5	5
Data - Mission C				
Annual cycles:	1100			
Annual Flight Hours:	3300			
Average sector length (Hours):	3			
Additional fuel per sector - A320* (KGs):		15	8	8

*Figures represent additional fuel burn and cost for an A320 aircraft. For A318, A319 and A321 the factors shown on page 37 should be applied.

Figure 4-28
Typical Paint Peeling on Nose, Upper and Lower Wings (A320* - fixed fuel price)

References: Typical Paint Peeling	
MPD Task Reference:	nose ZL-100-02 and ZL-200-02, wings ZL-500-02
MPD Task Interval:	every 100 days
Estimated inspection time (nose and wings):	30 minutes
Estimated repair time:	depends on extent of damage
AMM Reference:	51-23-00 PB201
SRM Reference:	51-75-12

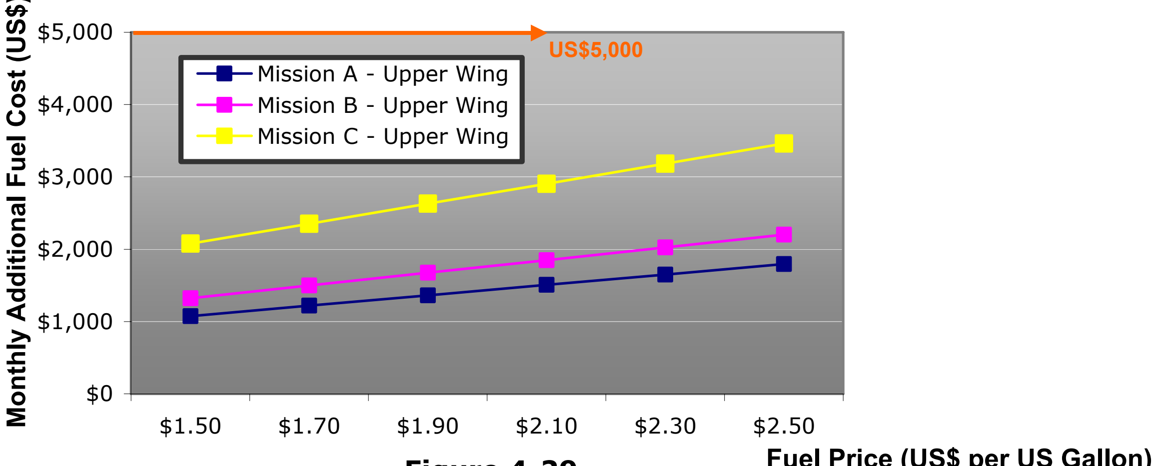
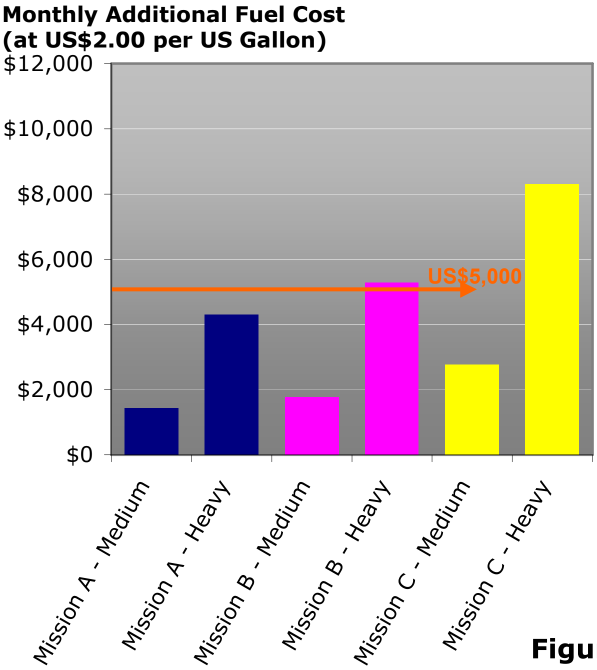


Figure 4-29
Typical Paint Peeling – Upper Wing
(A320* - variable fuel price)

4.3.3.9 AIRCRAFT EXTERIOR CLEANING

The natural accumulation of dirt on the aircraft's external surface will introduce a slight roughness that, overall, can induce significant additional drag. There is no standard definition of how dirty is a "dirty aircraft" and so this assessment can only give an indication for the potential fuel penalty.



		Dirt Accumulation	
		Medium	Heavy
Data - Mission A			
Annual cycles:	1800		
Annual Flight Hours:	2700		
Average sector length (Hours):	1.5		
Additional fuel per sector - A320* (KGs):		**10**	**29**
Data - Mission B			
Annual cycles:	1500		
Annual Flight Hours:	3000		
Average sector length (Hours):	2		
Additional fuel per sector - A320* (KGs):		**11**	**32**
Data - Mission C			
Annual cycles:	1100		
Annual Flight Hours:	3300		
Average sector length (Hours):	3		
Additional fuel per sector - A320* (KGs):		**15**	**45**

*Figures represent additional fuel burn and cost for an A320 aircraft.
For A318, A319 and A321 the factors shown on page 37 should be applied.

Figure 4-30
Medium and Heavy Dirt Accumulation (A320*- Fixed Fuel Price)

References: Dirty Aircraft	
MPD Task Reference:	N/A
MPD Task Interval:	N/A (according operator requirements)
Estimated inspection time:	N/A
Estimated time to clean aircraft:	N/A
AMM Reference:	12-21-11 PB301

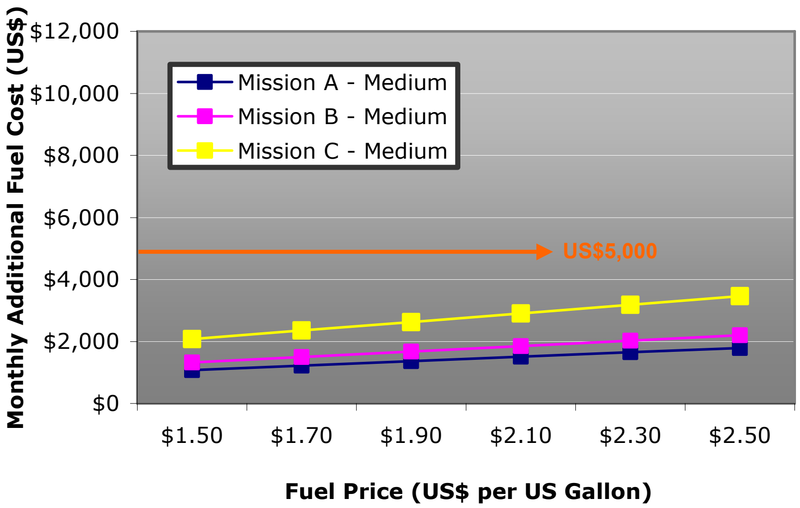
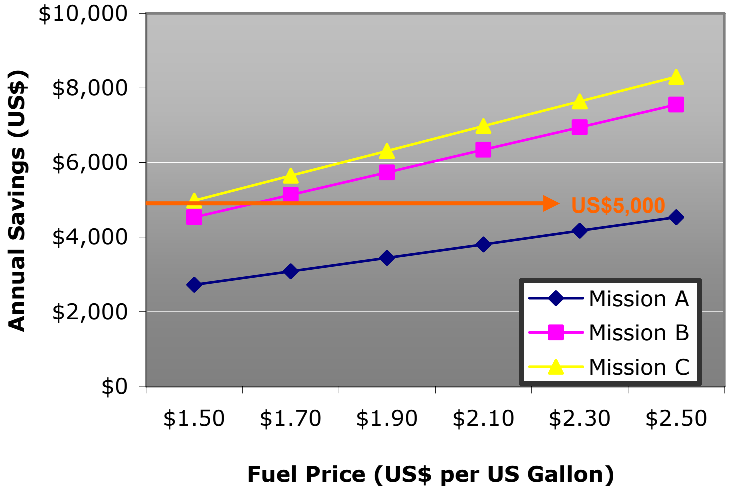


Figure 4-31
Medium Dirt Accumulation (A320* - variable Fuel Price)

4.3.4 WEIGHT REDUCTION

A reduction of 100 kilograms of aircraft weight will save between 3 and 9 kilograms of fuel on a typical sector flown by an A320 Family aircraft. Over the course of a year this translates into a saving in fuel ranging from US$3,500 to in excess of US$6,500 (varies with utilization and based on fuel at US$2.00 per US Gallon).



Data - Mission A	
Annual cycles:	1800
Annual Flight Hours:	2700
Average sector length (Hours):	1.5
Fuel economy per sector (KGs):	**3**
Data - Mission B	
Annual cycles:	1500
Annual Flight Hours:	3000
Average sector length (Hours):	2
Fuel economy per sector (KGs):	**6**
Data - Mission C	
Annual cycles:	1100
Annual Flight Hours:	3300
Average sector length (Hours):	3
Fuel economy per sector (KGs):	**9**

Figure 4-32
Aircraft operating weight reduced by 100kg

This section of the document highlights initiatives and aircraft modifications that can reduce the aircraft's weight.

4.3.4.1 AIRCRAFT INTERIOR CLEANING

Section 4.3.3.9 discussed the aerodynamic consequences of exterior contamination. There is also a secondary consideration of the weight of this contamination and this leads to considering the general cleanliness of the interior of the aircraft. Most operators recognize the importance of cabin cleanliness from a passenger comfort perspective but keeping the passenger and crew areas clean will have the added benefit of minimizing weight increase through dirt accumulation.

Regular cleaning of cargo compartments should also be considered. Apart from helping to minimize weight this can allow help to reduce maintenance costs. Foreign objects such as broken suitcase handles or wheels can cause cargo compartment panel damage. Cleaning can also minimize maintenance costs associated with the Cargo Loading System (CLS - when installed) by for example reducing the Power Drive Unit (PDU) roller rubber wear/damage.

Reference documents
SIL 00-032 – Aircraft System Maintenance Aids
(table III refers to CD-ROM - Cargo Hold Maintenance- Sept 00, ref. SEE25/94A.8806/04 - applicable to A320 Family equipped with CLS)
Point of Contact: remi.denizot@airbus.com

The cleanliness of other areas such as APU, hydraulic and avionic bays should also be considered. Maintenance teams should be briefed on appropriate procedures for dealing with dust or fluid contamination and encouraged to apply them whenever it is found during the course of their work.

4.3.4.2 CONDENSATION

Airbus aircraft are designed to minimize condensation formation and drain condensation that may form wherever possible. Nonetheless, studies suggest that an aircraft of the A320 Family can accumulate and retain in excess of 200 kilograms of water.

Condensation and associated moisture issues are greatly affected by seating density, load factor and utilization. A high utilization brings with it an increase in the time the structure is exposed to the lower temperatures that cause condensation. Furthermore, short turnaround times may not allow full evaporation or drainage of the condensed water to take place.

> **Reference documents**
> SIL 21-129 – Cabin Condensation Activities
> SIL 21-051 – Cabin Water Condensation
> Point of Contact: nigel.dadswell@airbus.com

Careful maintenance of insulation blankets, particularly in the upper fuselage area will minimize un-insulated cold sinks and reduce condensation.

4.3.4.3 REMOVAL OF GALLEY COMPONENTS

For certain types of short haul operations it can be appropriate to remove some or all water heaters/ coffee makers and ovens from the aircraft’s galleys. Hot water or beverages can be carried in insulated portable dispensers.

Component	**Component Weight (varies with model)**	**Number fitted to aircraft (typical example)**	**Total Weight (typical configuration)**
Water Heater	up to 12 Kgs	2	up to 24 Kgs
Coffee Maker	up to 18 Kgs	2	up to 36 Kgs
Oven	up to 22 Kgs	4	up to 88 Kgs
		TOTAL	up to 148 Kgs

Figure 4-33
Weight savings when removing galley components

Deletion of galley components is achieved through the application of the appropriate galley vendor service bulletin. Galley components may also be removed temporarily once approval from the galley manufacturer and the local aviation authority has been granted.

Removal of these components allows aircraft weight to be reduced and also removes the need to, and cost of, maintaining them.

4.3.4.4 SAFETY EQUIPMENT

Safety equipment requirements are agreed between the aircraft operator and the local aviation authority. Typically, aircraft that are to be employed in over-water operations will be equipped with emergency slide rafts. However, for overland routes it may be possible to justify swapping slide rafts for basic slides.

Component	**Component Weight**	Total weight saving converting slides (4 per aircraft) from slide raft to basic slide = **128 Kgs**
Slide Raft	57 Kgs	
Basic Slide	25 Kgs	

Note: over-wing exits are equipped with basic slides only.

Figure 4-34
Weight savings when converting slides

This initiative will bring fuel cost savings of around US$4,600 to US$8,500 per aircraft per year (varies with utilization and based on fuel at US$2.00 per US Gallon).

Conversely, the installation of over water equipment can allow more direct routes to be flown, thus reducing trip fuel.

4.3.4.5 POTABLE WATER UPLOAD REDUCTION

Aircraft of the A320 Family are equipped with a potable water tank that can hold up to 200 liters, i.e. 200 Kgs. The tank is refilled via the servicing panel at lower left-hand side of the rear fuselage and tank contents are indicated on a gauge on the servicing panel and on the Forward Attendants Panel (FAP).

More and more airlines provide their passengers with bottled drinking water and so the potable water is actually only used in the toilets for washing hands and flushing the lavatory (which nominally consumes about 0.2 liters of water per flush).

Some aircraft are equipped with a system that allows the tank to be refilled to a pre-selected level (25%, 50% or 75% full, i.e. 50, 100 and 150 liters). For aircraft not equipped with the pre-selection system a simple alternative can be developed if the flow rate of the refill system is known (e.g. if the refill rate is 10 liters every 20 seconds, and 50 liters is required, then a "100 second replenishment" will be needed).

4.3.4.6 WASTE TANK EMPTYING

Water from toilet waste basins is sent directly overboard via heated drain masts. All toilet waste is stored in the 200-liter waste tank. Clearly, increasing the frequency of tank emptying offers a potential for weight saving.

4.3.4.7 OTHER INITIATIVES

The table on the following page highlights a number of other initiatives that can reduce the aircraft's weight or drag. Their application, as with all recommendations in this document, should be carefully evaluated in terms of both benefits and costs.

Initiative Title	Benefit	Other Considerations	Applicability	Reference Documents
Use of radial tires	• Weight reduction of up to 136 KGs (all tires) – a few bias tires are lighter than their radial equivalent • Average landings per tire increased	• Cost per tire increase (cost per landing may be unchanged) • Weight saving varies with tire manufacturer. • Limited availability (during 2006 to 2008).	All aircraft fitted with bias tires	SB A320-32-1007
Removal of brake fans	• Weight reduction of between 12.6 and 25.0 KGs	• Increased brake cooling time and minimum aircraft turnaround time (up to 3 times longer) • Reduced maintenance costs through system deletion. • SB and kit cost	All aircraft fitted with brake fans	Depending on configuration SB A320-32-1151 SB A320-32-1264 SB A320-32-1275 SB A320-32-1280 SB A320-32-1322 MMEL item 32-47-01 cooling tables
Removal of Tire Pressure Indicating System (TPIS)	• Weight reduction of between 6.6 and 12.5 KGs	• MPD Tire pressure check must be carried out manually (additional time) • Reduced maintenance costs through system deletion. • SB and kit cost	All aircraft fitted with TPIS	SB A320-32-1202
Reshaped fuel tank NACA inlet	• 0.3% reduction in cruise drag. • Equals saving of between 10 and 20 KGs of fuel per flight.	• SB and kit cost (RFC/RMO process).	All pre-mod aircraft. Production std from mid-2007.	SB A320-28-1158
Avionic Ventilation System Filters	• Weight reduction of 6 KGs	• Improved filter performance possible.	All pre-mod aircraft. Production std from mid-2003	SB A320-21-1139
Removal of brake bands	Weight reduction of 5.5 KGs		All A/C fitted with brake bands	SB A320-32-1217
Use of "S-glass" cargo bay lining panels (roof and sidewalls)	• Weight reduction of between 15 KGs (A318) and 32 KGs (A321).	• Panels nominally replaced on attrition basis • Improved damage tolerance and reduced maintenance costs	Embodiment points vary with type and cargo bay standard. First delivery end Sept. 2004	IPC (S-glass panels listed as preferred parts)
Removal of cargo loading system (CLS)	• Weight reduction of 180KGs on A320	• Requires revised floor panels and some structural modifications. • SB and kit cost (RFC/RMO process).	Aircraft equipped with CLS.	Contact Airbus Upgrade Services
Reduction of in-flight magazines.	• Weight reduction of between 15 KGs (A318) and 25 KGs (A321) if number or weight reduced by one third.	• Reduced reproduction costs	All operators producing in-flight magazines in paper format.	

4.3.4.8 AIR DATA SYSTEM ACCURACY

To conclude this section of the document, a brief mention of the "air data" system. This system measures the aircraft's altitude and speed through the air. In sections 4.2.3.1 and 4.2.3.2, the importance of accurately flying to calculated speeds and altitudes was discussed. Clearly, if the air data system is mis-calibrated, it will not allow this objective to be achieved. The air data system of the A320 Family of aircraft does not, unlike some types, require or benefit from any sort of calibration. Any system fault will result in a warning to the crew. However, regular cleaning of the air data system's sensors (on the exterior of the aircraft) and the network of piping that relays the air to the avionics system for processing is part of the aircraft's scheduled maintenance program.

Reference documents
MPD Task: 341300-07-1
Point of Contact: xavier.barriola@airbus.com

5 SUMMARY AND CONCLUSIONS

Expenditure on fuel usually represents the single largest operational cost for any aircraft operator. In recent years, the proportion of this cost has increased significantly.

This document has been written to highlight the basic principles of, and main contributors to, fuel efficiency for in-service aircraft. References have been provided throughout for those wishing to explore any item more fully. Operators are also invited to contact Airbus to discuss the application of, or trade-off between, any of the initiatives mentioned. Discussion of any further initiatives is also welcomed. This may be initiated either through the points of contact referenced throughout the document, via your local Airbus resident support office, or via your Customer Support Director (CSD).

In the process of discussing factors that can influence fuel consumption, this document has also illustrated that many groups within an aircraft operator's organization have a role to play in reducing fuel consumption. As such, fuel conservation should not be considered as the responsibility of any single individual or function. Many airlines have created multi-function teams or committees to drive their fuel efficiency initiatives. However, responsibility for coordinating fuel conservation measures should be with senior management. Ensuring awareness of issues and initiatives throughout the organization should be included in the coordination activity. The distribution of fuel usage data outside the traditional operations environment and the introduction of employee suggestion schemes both have the potential to benefit the operation as does the development of briefing materials, either for individual use or in a more structured forum. For those on the "front line", such as dispatchers, pilots and maintenance crews, a more formal reinforcement of the selected initiatives may be appropriate through training and revised procedures. Operators that have implemented fuel efficiency programs often implement a means of monitoring fuel consumption, either globally or at fleet or even aircraft level. In general such a tool will not be able to determine the effectiveness of an individual initiative but it will provide a baseline and an indication of global progress.

The following table provides a summary of the initiatives mentioned in this document.

Category	Initiative Description	Overall Value	Reference
Generic	Nominate a transverse fuel efficiency team		
	Monitor fuel consumption		
	Monitor fuel prices and invoices		
	Review provision passenger service against its weight penalty		
	Raise overall organization awareness		
Operations	Optimize flight plan accuracy	***	4.2.3.3.
	Review routing internally and with ATC	**	
	Optimize fuel reserves	**	4.2.3.5.
	Monitor aircraft performance and weight	*	4.2.3.4.
	Reduce APU usage	*	4.2.4.2.
	Optimize use of single engine taxiing across network	**	4.2.4.4.
	Optimize Cost Index throughout schedule	***	4.2.2.
	Optimize use of fuel tankering for all routes	*	4.2.4.1.
	Optimize approach configuration for all airports / flights	*	4.2.4.11.
	Optimize use of thrust reverse for all airports / flights	*	4.2.4.12.
	Reinforce procedures and training	**	
Maintenance	Review airframe cleaning interval	*	4.3.3.9.
	Review engine wash interval	*	4.3.2.2.
	Review anti-condensation measures	*	4.3.4.2.
	Fast track resolution of MEL/CDL items with impact fuel consumption.	*	4.3.1
	Review interval of maintenance checks influencing aerodynamic efficiency.	*	4.3.3.
	Include fuel efficiency in cost / benefit assessment of SBs and other maintenance initiatives	*	
	Reinforce procedures and training	**	

We hope that you have found this document interesting and indeed helpful. Airbus will continue to optimize its support in this domain, not only for the A320 Family, but for all of its products. We encourage you to support us in this by sharing with us your view on the value of this document and the shape future developments should take.

Questions or comments on the generic content of this brochure or the subject of fuel efficiency:
Point of Contact: simon.weselby@airbus.com

APPENDICES

A. CONVERSION FACTORS

42 US Gallons .... per US Barrel
42 Imperial Gallons .... per Imperial Barrel
0.833 Imperial Gallons .... per US Gallon
3.78 Liters .... per US Gallon
4.55 Liters .... per Imperial Gallon
0.787 Kilograms Fuel .... per Liter (standard fuel density)
2.98 Kilograms Fuel .... per US Gallon (standard fuel density)
3.58 Kilograms Fuel............ per Imperial Gallon (standard fuel density)

B. ABBREVIATIONS

ACARS.................... Aircraft Communication Addressing and Reporting System
AMM....................... Aircraft Maintenance Manual
APM .... Aircraft Performance Monitoring (PEP module)
APU........................ Auxiliary Power Unit
ATA........................ Air Transport Association (http://www.airlines.org)
ATC........................ Air Traffic Control
CDL .... Configuration Deviation List
CFP .... Computerized Flight Plan
CG .... Centre of Gravity
CLS........................ Cargo Loading System
CO_2........................ Carbon Dioxide
CSD .... Customer Support Director
ECS........................ Environmental Control System
EGT .... Exhaust Gas Temperature
FAP .... Flight Attendants Panel
FCOM .... Flight Crew Operating Manual
FLIP .... Flight Planning (PEP module)
FM .... Flight Manual
FMGS .... Flight Management and Guidance System
FMS .... Flight Management System
GCU .... Ground Control Unit
HPT........................ High Pressure Turbine
IATA .... International Air Transport Association (http://www.iata.org/)
ICAO .... International Civil Aviation Organization (http://www.icao.int/)
IDG........................ Integrated Drive Generator
IFP......................... In-Flight Performance (PEP module)
IPC .... Illustrated Parts Catalogue
KG(s) .... Kilogram(s)
MEL .... Minimum Equipment List
MMEL .... Master Minimum Equipment List
MPD .... Maintenance Planning Document
NO_X........................ Nitrogen Oxides
PDU .... Power Drive Unit
PEP .... Performance Engineering Program
PFR .... Post Flight Report
SFC........................ Specific Fuel Consumption
SID .... Standard Instrument Departure
SRM .... Structure Repair Manual
TPIS....................... Tire Pressure Indicating System

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