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Aircraft Operational Fuel Savings & Noise Reduction - Past and Future

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DDCL & Royal Aeronautical Society

1. **INTRODUCTION** – Page 2
 2. **A SIMPLIFIED AIRCRAFT FLIGHT PROFILE** – Page 4
 3. **PRE-FLIGHT PLANNING** – Page 6
 4. **DEPARTURE NOISE ABATEMENT PROCEDURES** – Page 6
 5. **CRUISE FUEL SAVINGS** – Page 8
 6. **SITUATIONAL AWARENESS DURING CRUISE** – Page 11
 7. **DESCENT** – Page 13
 8. **APPROACH** – Page 15
 9. **STEEP APPROACHES TO REDUCE APPROACH NOISE** – Page 19
 10. **CREWS ABILITY TO SAVE FUEL / TIME BY CHOOSING THEIR OWN APPROACHES** – Page 19
 11. **PAST EXAMPES OF FUEL SAVED OPERATIONALLY** – Page 21
 12. **POSSIBLE FUTURE OPERATIONAL FUEL SAVINGS** – Page 24
 13. **“FUTURE” AIR TRAFFIC MANAGEMENT FUEL SAVINGS ACHIEVED NOW - USA** – Page 29
 14. **“FUTURE” AIR TRAFFIC MANAGEMENT FUEL SAVINGS ACHIEVED NOW - Europe** – Page 31
 15. **ACCIDENTS WHICH NEED NOT HAVE HAPPENED** – Page 32
 15. **CONCLUSION** – Page 36
- Appendix A – Part of the History of Continuous Descent Approaches
into London Heathrow Airport Starting in 1975** – Page 37

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1. INTRODUCTION

Fuel Efficiency - Needed in the Past for Airline Profitability – Vital in Future for the Environment and Survival of the Industry

Efficient use of fuel has always been fundamental to a profitable airline operation, even when aviation fuel was 11 US cents per gallon excessive fuel uplift could restrict payloads on critical sectors which would directly affect revenue and profitability.

However fuel was then a small part of overall costs so that other factors such as high speeds for time keeping could be a priority and inefficient operations had relatively little effect on the bottom line. When the price of fuel started to rise dramatically in the 1970s airlines which did not refine their procedures soon became unprofitable.

Some airlines in the 1970s concentrated on reducing fuel burn so as also to minimise the adverse effect on the environment, now every single operator has to be aware of the absolute need to reduce pollution to comply with future emission targets, otherwise the industry may not survive in its present form.

Aircraft Noise Reduction – Considered by some Currently to be the Most Critical Factor in Aircraft Operations. Can be a Compromise with Fuel Efficiency.

Inefficient Operations causing Excess Noise might lead to Airports being Relocated Unnecessarily.

Complaints of aircraft noise have been with the airline industry since the 1920s – in 1926 Varney Airlines in the USA received a letter from berry pickers about headaches caused by aircraft noise restricting their work. **The noise from jet aircraft introduced in the 1950s just after takeoff was extreme** and procedures had to be introduced to make the takeoff noise bearable below the aircraft's initial climb profile. These did bring a fuel penalty and noise departure routings were introduced in heavily populated areas which increased the route distance with a further increase in fuel used.

Jet aircraft takeoff noise was reduced significantly when big fan engines were introduced in the 1970s and some airlines refined their departure procedures to improve fuel efficiency, however some states still do not approve these procedures even in areas where noise is not a factor thereby wasting large amounts of fuel and increasing emissions close to the ground.

Initially no procedures were introduced to reduce jet aircraft noise on the approach, no doubt because a stabilised approach was considered vital to reduce the high accident rates during approach and landing. However some operators were configuring their aircraft for landing excessively early and ATC was requiring slow speeds for vectoring on approach requiring flaps increasing drag to be extended early.

These procedures were causing unnecessarily high noise levels on approach many miles from the airfield which could be similar to the unavoidable noise levels during departure. The extra fuel burnt could exceed that of a normal operation by over 50% on a short sector.

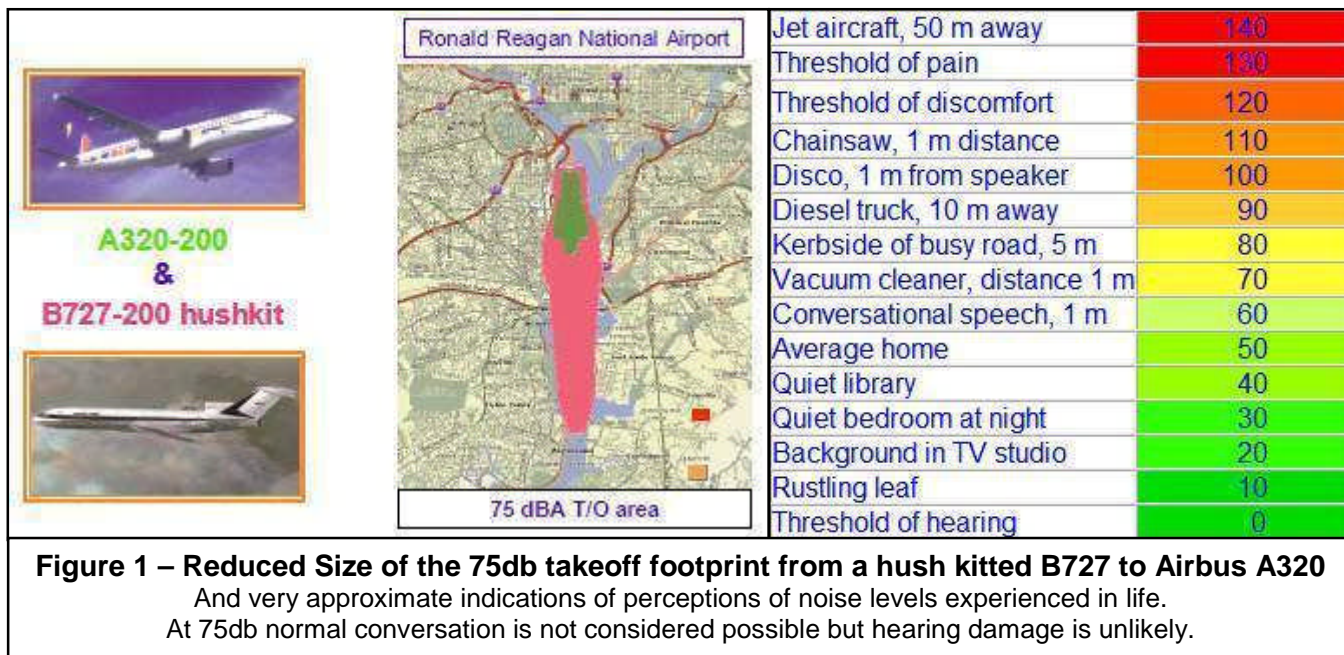
In the mid 1970s some airlines urged that higher speeds be used by ATC on approach and that operators be encouraged to configure their aircraft by extending the undercarriage/gear after the aircraft had been established on the final approach glide slope and so avoid flying level at low altitude with the gear extended, and these approach procedures were adopted by IATA.

Constant Descent Approaches were introduced into London Heathrow airport in 1975 to reduce aircraft noise on the approach, but the procedure has taken many years to be adopted properly by aircraft crews perhaps because the procedure has not yet been included in the aircraft manufacturers' operations manuals as an approved procedure. Also it is more difficult for an Air Traffic Controller to set up an optimally spaced stream of aircraft to the runway if aircraft during approach are trying to fly CDAs with different degrees of success. Future Air Traffic Management System will allow efficient CDAs to be flown from cruise altitude and some airlines such as UPS into Louisville have achieved this already as described on pages 29 - 30.

Steeper approaches than the standard 3° glidepath which has proved most suitable for safe arrivals can reduce noise by keeping aircraft higher close to the airport. Steep approaches have been operated by the quieter STOL (Short Takeoff and Landing) turboprop aircraft for many years, permitting approaches into airfields close to down town areas. Some small jet aircraft are also cleared for these operations and Airbus have recently been given approval for their smallest aircraft the A318 to operate into London City airport.

But to fly a steep approach the A318 needs changes to its control laws to create extra drag and this facility is not expected to be developed for larger aircraft in the foreseeable future.

Improvements in aircraft technology have obviously brought the largest improvements in fuel efficiency and noise reduction in recent years. This can be seen by Figure 1 showing that the size of the 75db noise footprint after takeoff of an Airbus A320 has been reduced by about 75% compared to a hush kitted Boeing 727 – and early turbojet powered aircraft without hush kits were even noisier creating a larger nuisance on the ground.



IATA confirms that technology has obviously improved aircraft efficiency considerably over the years – by 70% over 40 years, 20% in the past 10 years and airlines are looking for a 25% fuel efficiency improvement by 2020.

However flight crew still can have a large effect on the efficiency of the operation and this paper is aimed primarily for the interest of people who are not familiar with aircraft operations. Past examples are shown to illustrate that minor changes in operation can save at least 1% at no cost – in comparison one engine manufacturer currently spends over £800,000,000 per year in Research and Development to improve consumption by about 1%. The paper shows how some operators were able in the past to reduce their fuel burn by nearly 10% virtually overnight.

Most operators use fuel monitoring systems to confirm aircraft performance and schedule any maintenance necessary to keep aircraft operating close to the “book”, and some airlines use the programme to assess individual crew member’s fuel usage both in uplift of extra fuel and the amount of fuel burnt in flight against the norm. An example is shown of fuel monitoring in a small airline showing that the cost of fuel usage between pilots could vary by US\$100Ks per year. In another case the fuel savings by crews contracted to operate for a scheduled airline over the previously contracted crews exceeded the total cost of the crews.

Future improvements will only be implemented fully if the flight crew can make best use of the new technology. Automatics have contributed greatly to the improvements in safety and efficiency, however automatics on their own would undoubtedly cause a reduction in safety as human brains are required in the cockpit to resolve the unexpected problems/failures which inevitably arise. Also in normal operations without failures, humans in the cockpit are best able to determine the most efficient course to take as circumstances change in flight.

Similarly automatics alone, even if perfect, would be less efficient as strictly structured flights would have to be followed without the tactical flexibility that a human in the cockpit can provide.

To those who suggest that as pilot error is the most frequent accident cause removal of the pilot should improve safety, scientists will point out that the statistics do not show how many accidents flight crews have saved. A brief study of operators’ Mandatory Occurrence Reports which must be submitted to their Authorities for each significant system failure should prove convincing. Data shows that some accidents have been caused by failures that were not anticipated during the system design and thus had to be resolved tactically by the crew without checklists/procedures. The paper discusses how flight crews procedures have affected aircraft noise in the past and how they should be able to use current and impending technology to optimise efficiency, reducing fuel burn/emissions and aircraft noise in the quest to meet the future demands on the industry.

A final comment is made that **the profiles that produce more efficient and quieter approaches are also safer as they keep the aircraft well above the ground during the approach. If such procedures using Constant Angle Non Precision Approaches defined by DME-Altitude information had been introduced when available in the mid 1970s, many lives could have been saved during the following 30 years.**

2. A SIMPLIFIED AIRCRAFT FLIGHT PROFILE

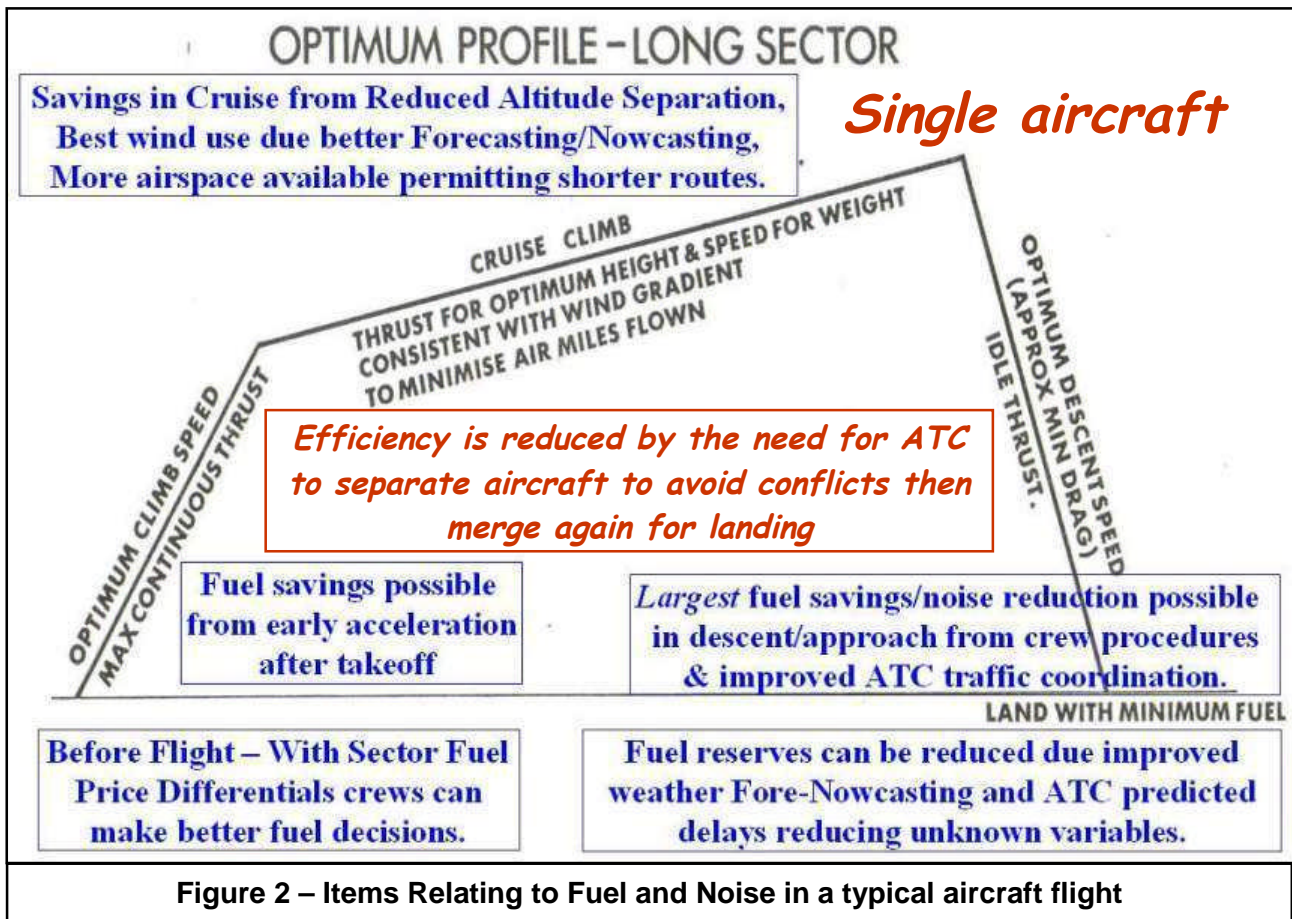


Figure 2 shows a simplified optimum profile of a long sector where the aircraft accelerates immediately after takeoff to climb at optimum speed with a Maximum Continuous or Climb engine Thrust to its optimum cruise altitude for its current weight. Engine thrust limits are determined by the engine manufacturer to give acceptable levels of reliability and engine life.

The aircraft then Cruise Climbs with Max Cruise Thrust as fuel is burnt off until starting descent, which should be made with idle thrust at optimum speed to the approach phase. During approach the crew slows the aircraft, selecting flaps as required to establish the landing configuration efficiently with the gear down and landing flap for a safe landing.

The aircraft should arrive with minimum fuel to keep the aircraft weight as low as possible, which can be determined by the inputs to the flight planning system. These inputs include factors such as accurate wind forecasting, probability of Air Traffic Control not assigning the planned route and altitudes, extra fuel needed for possibilities of aircraft system failures (eg engine or pressurisation) requiring diversion to an en route alternate, ATC delays at the destination, etc.

The route and altitudes flown should take maximum benefit of the prevailing wind. Figure 9 illustrates the strong winds that exist in the atmosphere and how they can change significantly in direction and strength. Routes and altitudes must be chosen to take advantage of tailwinds and avoid headwinds. Optimum routes for long flights can therefore change geographically by large distances – for example on the North Atlantic where Westbound flights routinely fly longer more Northerly routes to avoid the jet streams further South. Airspace and ATC systems should allow flexibility in the route structure to allow optimum routes to be flown, but this is difficult in many areas due to political constraints.

Such an ideal flight might have been achieved in the 1950s by the Comet 1s which were alone in the sky at high altitudes but accurate wind information and on board navigational systems were not then available. Concorde could cruise climb because there was no conflicting traffic at their cruise altitudes from 45 to 60,000ft.

Now aircraft can always be updated with accurate weather information, but many current ATC systems cannot accommodate the most efficient profiles except in areas of low traffic density. However even in areas where airspace should not be limiting such as in the South Pacific, as airlines schedule many aircraft departures close together around the best commercial times a number of aircraft currently may have to operate on non-optimum profiles.

As new generation ATM systems come on line flights should be able to achieve close to the optimum profiles, horizontally and vertically as seen now in parts of North America and Europe in Scandinavia and described later. Fuel could be saved when aircraft are bunched together commercially by reducing the minimum distance allowed between aircraft by Self Separation to keep more aircraft close to the optimum route, before the complete new ATM systems are in place.

Items mainly covered in the paper are shown in blocks in Figure 2.

3. PRE-FLIGHT PLANNING

Computer flight planning systems have been in service for some 30 years and are now fed with reliable forecast wind information so that flight plans presented to crews are now generally extremely accurate, but last minute variables still exist such as the aircraft weight dependent on the passenger and/or cargo payload.

The crew has the final decision on a how much fuel to carry. Extra fuel over the minimum flight planned requirement would depend upon the crew's judgement on the possibility of other factors occurring which have not been accounted for in the flight plan – eg extra ATC delays, inability to obtain the planned route, aircraft performance degradation, etc.

However a sensible economic decision for the amount of extra fuel based on the probable risk of such an event occurring cannot be made without knowing the cost of fuel for that flight, which is dependent on the relative cost of fuel between the departure and destination airfields.

Extra fuel is burnt at the rate of about 3% per flight hour due to the additional aircraft weight, so there is always a fuel penalty in carrying extra fuel. However as Figure 5 shows, if the fuel at departure is sufficiently cheap it can be economic to “tanker” fuel to the destination.

However the effect of the extra aircraft weight must also be considered – the ability to achieve optimum cruise levels, the extra braking required on landing and need for reverse thrust, need to back-track the runway if a turn off to a taxiway is not possible, etc.

Only the crew is really capable of making a sensible decision on the day. From Figure 5 – tankering LHR-BRU for a saving of US\$1.00 per tonne would not be worthwhile for economics alone, unlike HKG-NGO at \$127 saving per tonne. Yet some operators do not indicate the relative cost and only tell crews whether or not they should “tanker”, which may not be beneficial in some operational circumstances on the day.

The cost of carrying extra fuel varies considerably from US\$1.00 per tonne HKG-DEL which might be cheap insurance against a possible delay/diversion whereas at US\$206 NGO-HKG such insurance is prohibitive.

The cost of extra fuel carriage can be surprisingly high on some sectors, eg US\$122 DXB-HKG. Before these figures were published one crew carried an extra 40 tonnes on an empty aircraft to give a better landing weight for training. The cost of nearly US\$5,000 put them at the bottom of the fuel monitoring graph, shown in Figure 31, for several months!

The cost of carrying extra fuel cannot be established properly without knowledge of Sector Fuel Price Differentials.

Fuel Price Differentials		
Cost (US\$) of 1 tonne Extra Fuel Uplifted on Departure		
Dep	Dest	1 Tonne Extra Fuel
BKK	DXB	Cost +\$5
BKK	HKG	Cost +\$20
BRU	DXB	Cost +\$15
BRU	HKG	Cost +\$107
BRU	LHR	Cost +\$12
BRU	MAN	Cost +\$3
DEL	DXB	Cost +\$35
DXB	BKK	Cost +\$101
DXB	BRU	Cost +\$110
DXB	HKG	Cost +\$122
DXB	LHR	Cost +\$119
DXB	MAN	Cost +\$113
DXB	MUC	Cost +\$62
HKG	BKK	Cost +\$18
HKG	DEL	Cost +\$1
HKG	DXB	Cost +\$18
HKG	KTM	Save -\$70
HKG	NGO	Save -\$127
HKG	SIN	Cost +\$26
KTM	HKG	Cost +\$169
LHR	BRU	Save -\$1
LHR	DXB	Cost +\$15
LHR	HKG	Cost +\$109
MAN	BRU	Cost +\$12
MAN	DXB	Cost +\$29
MAN	HKG	Cost +\$121
MUC	BRU	Cost +\$58
MUC	MAN	Cost +\$59
NGO	HKG	Cost +\$206

Figure 5 – Cost of carrying 1 tonne of extra fuel between 2 airfields

4. DEPARTURE NOISE ABATEMENT PROCEDURES

The noise from the early turbojet aircraft at takeoff thrust during departure in the 1950s and early 1960s was so deafening that a procedure had to be produced to make life tolerable close to the airport under the flight path. This was agreed by IATA and is shown as the Noise Abatement Departure Procedure NADP 1 on the left of Figure 6.

The extremely loud noise/crackle from the fast, hot exhaust gas from the turbojet engines could be alleviated on the ground by reducing from takeoff to climb thrust as soon as practicable but still climbing at takeoff speed to gain altitude high enough to reduce the ground noise to an acceptable level before accelerating, normally about 3,000ft. Some engines were so noisy even at climb thrust that a lower thrust setting was used to climb to 3,000ft, taking considerably longer before starting to accelerate and retract the flaps. (The Airbus A380 automates this procedure as in Figure 7.)

This procedure is inefficient because the aircraft is in a high drag configuration with wing flaps extended for a long time before the aircraft can accelerate to flap retraction speeds.

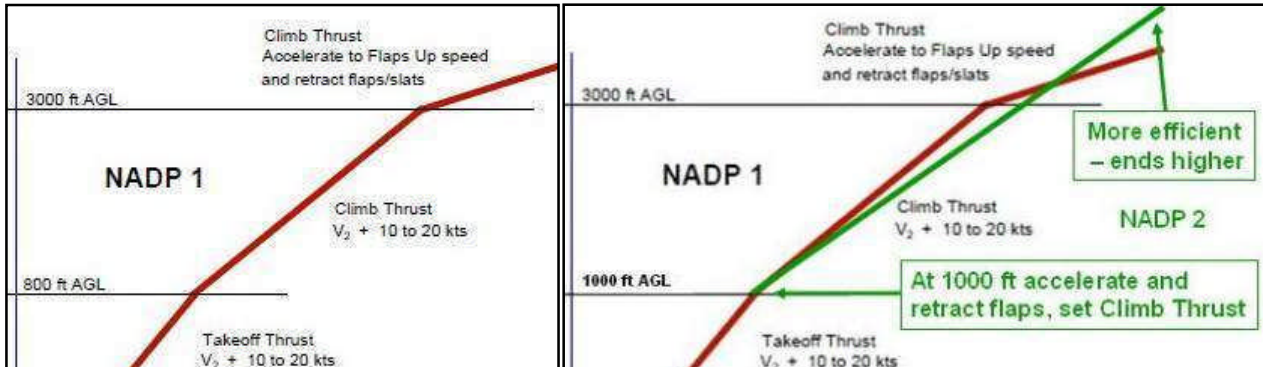
Turbofan engines with cooler slower exhaust streams were quieter and exhibited less noise reduction by climbing higher before acceleration. North West Airlines introduced a more fuel efficient Noise Abatement Procedure adopted by the ATA (American Transport Association) airlines in the mid 1970s which became the IATA NADP 2 in green on the right in Figure 6.

Instead of climbing to 3,000ft at takeoff speed before accelerating to retract the flaps, acceleration is started at about 1,000ft while still maintaining a positive rate of climb and the flaps retracted on reaching the requisite speed(s). Climb thrust is set during flap retraction according to aircraft type.

The NADP 2 procedure is more efficient as the aircraft spends less time in a high drag configuration with the flaps extended, and generally ends some 500ft higher when at final climb speed than with NADP 1. Fuel savings depend upon aircraft type but about 2% can be saved on a 400 nm sector as shown on Page 22.

A minimum altitude of 400ft above the runway is required by performance regulations before the aircraft can accelerate – most operators using NADP2 start accelerating at 1,000ft but starting at a lower altitude will save more fuel.

Many airlines adopted NADP 2 for fuel savings in the 1970-80s but **some European states still stipulate NADP 1 as the required departure procedure out of their airports. This is costing airlines who comply with this procedure significant quantities of fuel per year besides unnecessarily increasing emissions close to the ground.**



**Figure 6 - Comparison Between:
1960s NADP 1 - Initial IATA Procedure for Early Very Noisy Turbojets and
1970s NADP 2 – More Fuel Efficient ATA Procedure from NWA for Quieter Fanjets**

London Heathrow has the most restrictive departure noise requirements and airlines have developed special procedures to be able to operate at the highest takeoff weights while keeping below the noise limit.

The Airbus A380 superjumbo has an automatic takeoff regime which selects the optimum thrust and departure profile to comply with the Heathrow requirements shown in Figure 7 – similar in ways to the technique used by the very noisy early turbojets which reduced to below climb thrust until reaching 3,000ft.

This procedure is part of the noise reduction features which Airbus introduced on the A380 shown in Figure 8 making the aircraft the quietest large jet airliner currently in service.

Airbus designed the wing flaps for optimum low speed performance which requires the lowest thrust to give good climb performance, and designed the airframe to generate minimum noise.

Engine nacelles were optimised for good performance combined with low noise generation and Rolls-Royce increased the fan size on its Trent 900 engines in order to help meet the LHR takeoff noise requirements thereby incurring a fuel penalty of about 1%.

This illustrates the current compromise between fuel efficiency and noise reduction.

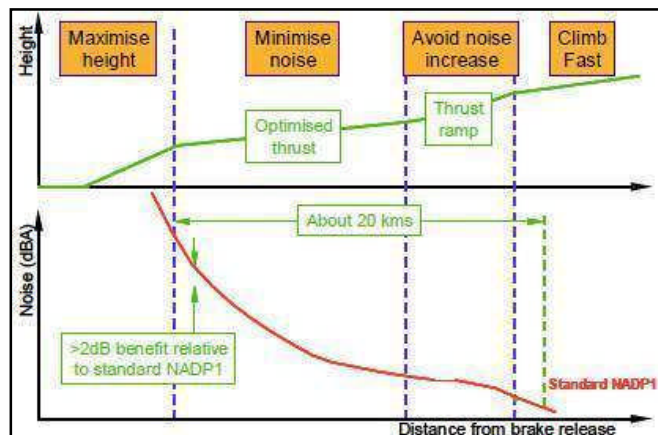


Figure 7 - Airbus A380 LHR Departure
After initial climb and thrust reduction, engine thrust is selected automatically to create the minimum noise while climbing to an altitude when the aircraft can accelerate to normal climb speed.

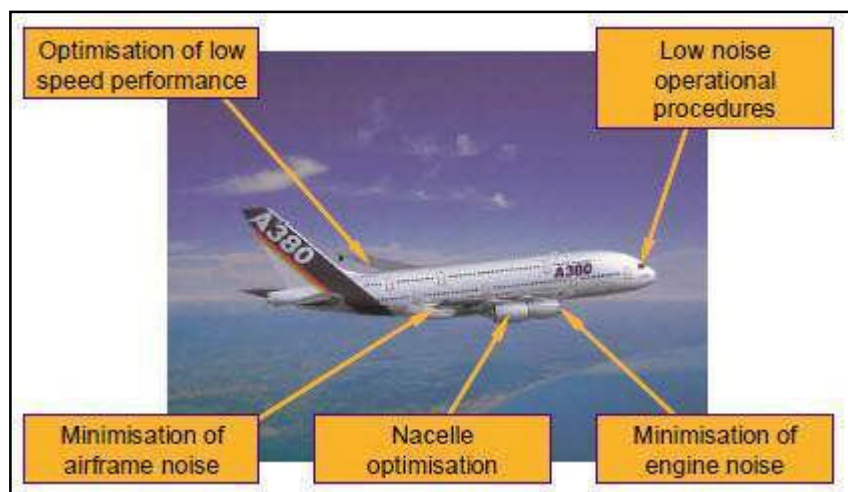


Figure 8 - Airbus A380 Noise Reduction Features

5. CRUISE FUEL SAVINGS

Figure 9 shows how much energy can be used – or must be avoided – from winds in the atmosphere. The wind component in the direction 290°-110° has changed by 220kts over the same area.

Accurate weather forecasting is essential to flight plan optimum routes taking best advantage of the forecast wind patterns, which are currently supplied to aviation users by AMDAR.

Aircraft Meteorological Data Relay was started by the Australian Bureau of Meteorology in the mid 1980s.

From 2003 EUMetNet-AMNDAR became part of EUCOS observing system headed by the Swedish Met Service (SMHI) to manage the collective resources of the 10 contributing National Met Services to deliver the best available quality of meteorological information.

As indicated in Figure 10 information from aircraft of the participating airlines - Air France-KLM, British Airways, Lufthansa and SAS - in flight is used to update weather model.

Information is also provided for Wind shear, low level jets/turbulence, wake vortices, convection and thunderstorm development, low cloud/fog formation and duration, and for efficient approach control. Air Traffic Controllers can obtain current wind information from the AMDAR website.

In Sweden E-ADMAR supports the SAS Green Approaches into Stockholm Arlanda airport described on Page 31, where a local datalink to the aircraft and a system developed by Avtech enables “NowCasting” to refine the winds and temperatures to uplink to the aircraft for more accurate 4D navigation through efficient descent and approach profiles.

Except in oceanic areas it may not be possible to change air routes to make best advantage of the winds due to airspace restrictions by the military or for political reasons, etc. Freeing more airspace will improve fuel efficiency/reduce emissions at altitude.

Jet streams can exist in narrow altitude bands which aircraft want to fly with or avoid according to direction, so it is important for aircraft to be able to fly at its best altitude as well as along its optimum route. Vertical separation used to be 2,000ft above Flight Level 290 – 4,000ft in one direction on a bi-directional airway - due to the poor accuracy of aircraft altimeter systems. After the improved accuracy of current Air Data Systems had been established, reduced separation of 1,000ft to FL 410 was introduced in RVSM (Reduced Vertical Separation Minima) areas which now cover most of the world. With stepped climbs of 1,000ft the advantages of Cruise Climb are now small.

Above FL410 vertical separation reverts to 2,000ft and ATM (Air Traffic Management) developments such as ASAS (Airborne Separation Assistance Systems) may permit the more efficient cruise climb.

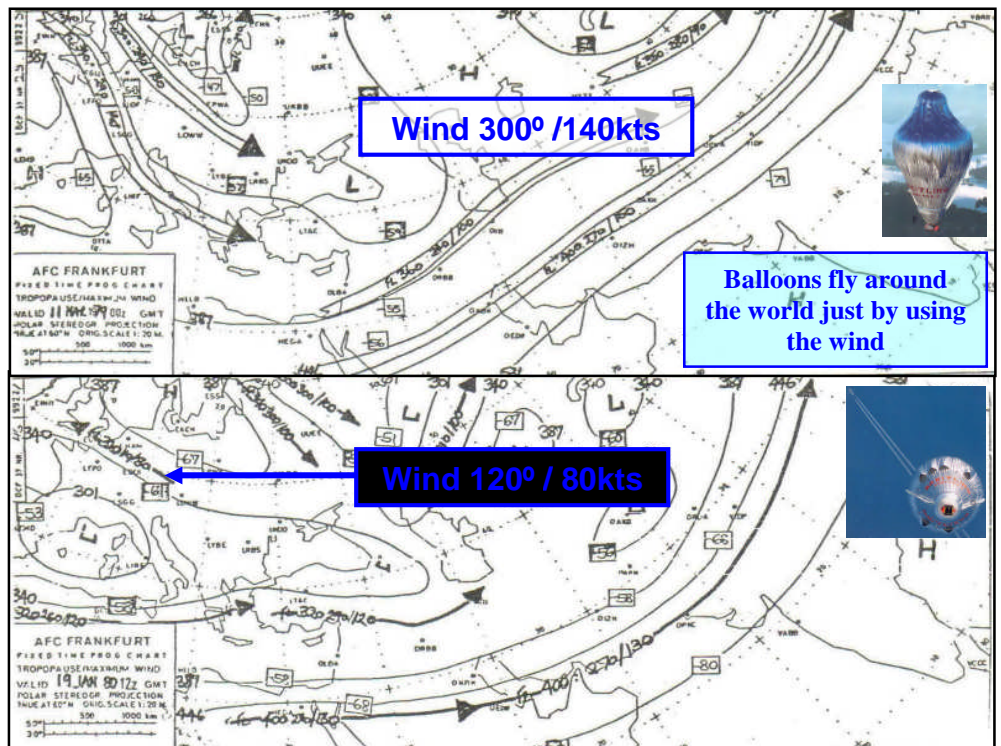


Figure 9 - Illustration of the Energy in the Upper Atmosphere and how Jet Streams can reverse direction by 180° / 220 kt component over the same area. Computer flight planning systems fed by accurate data from AMDAR now make best use of winds

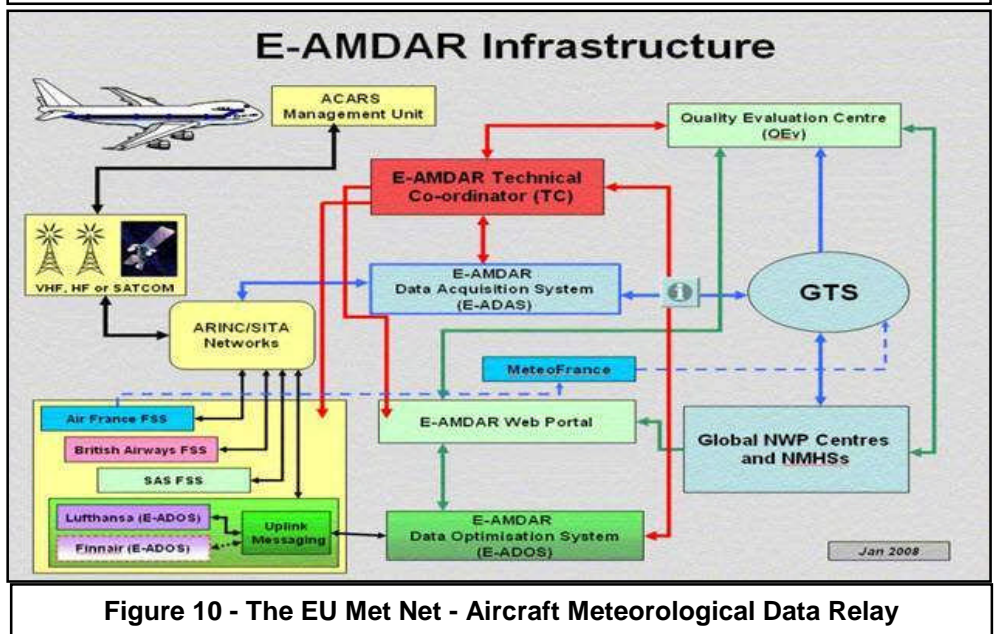


Figure 10 - The EU Met Net - Aircraft Meteorological Data Relay

Examples of Oceanic Routes –

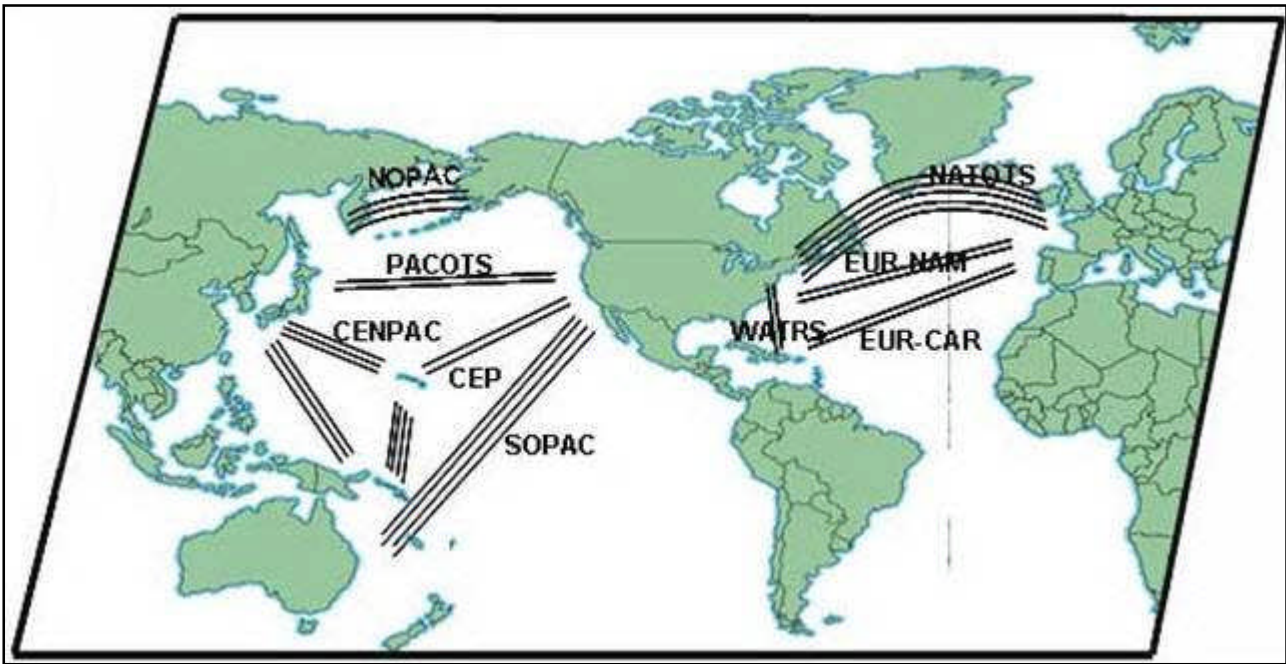


Figure 11 - Examples of Ocean Routes and Track Systems

Fixed routes – Not always efficient as do not vary to take advantage of winds

NOPAC – North Pacific Routes – Asia to Alaska

CEPAC – Central East Pacific Composite Airspace – Honolulu to US

CENPAC - Central Pacific Area – Asia to US

Organized Track Systems – In areas with heavy traffic and with strong, variable winds and weather. ATC Centres/Air Navigation Service Providers calculate the optimum tracks based on the forecast winds for the next period which are published for the use of the operators. Optimum altitudes may not be available when traffic is heavy, Winds in these areas can extremely strong – up to 250kts so flexible routes are essential to make maximum use of the winds.

NATOTS - North Atlantic Organised Track System –Canada/US to Europe

PACOTS - Pacific Organised Track System – Asia/Japan to US/Canada.

User Preferred Routes – In areas of low traffic so operators can choose their optimum route/profiles. Conflicts can exist when airlines leave at similar times thus limiting optimum profiles, but separation/penalties can be reduced by using ADS-B (Automatic Dependent Surveillance-Broadcast) described later in Page 27.

SOPAC – Southern Pacific routes – Australasia to the US.

EUR-CAR/NAM – Europe to the Caribbean/Southern US.

Aircraft can be unable to obtain climb clearance under current ATC standards to maintain their optimum altitudes as fuel is burnt off and weight decreases.

As more aircraft become equipped with the on board systems to permit ASAS (Airborne Separation Assistance Systems) described on Page 27, then some tracks may be designated as Free Flight Tracks to be used by ASAS capable aircraft.

Crews may obtain ATC clearance to change levels and speed having identified any conflicting traffic on their Navigation Displays and then maintaining the required separation.

- Concept still in the early stages of development
- FFT is an OTS track reserved for ASAS-capable aircraft
- Aircraft on the track can change speed and level at their own discretion
... but no lateral flexibility allowed
- Aircraft requires downstream clearance to re-enter managed airspace

Figure 12 – Self Separation on Free Flight Track

Example of Reduction of Separation after ADS-B is Enabled of about 115 nautical miles.

In Automatic Dependent Surveillance-Broadcast enabled areas, described on Page 27, the navigation information from aircraft FMS is passed to the ground stations and other aircraft, thus aircraft positions, etc, can be shown on aircraft and ground controllers' displays. Controllers can send commands/information and allow self separation between aircraft.

Figures 13a & b show that the current in trail separation is based on a 15 minute time interval (about 120 nautical miles at typical True Air Speed of 480 kts), but with ADS-B enabled separation can be reduced to 5 nm.



Figure 13a – Current Separation is 15 minute (about 120 n miles) Between Aircraft



Figure 13b – With ADS-B Enabled, Separation Between Aircraft can be Reduced to 5 nm

6. SITUATIONAL AWARENESS DURING CRUISE

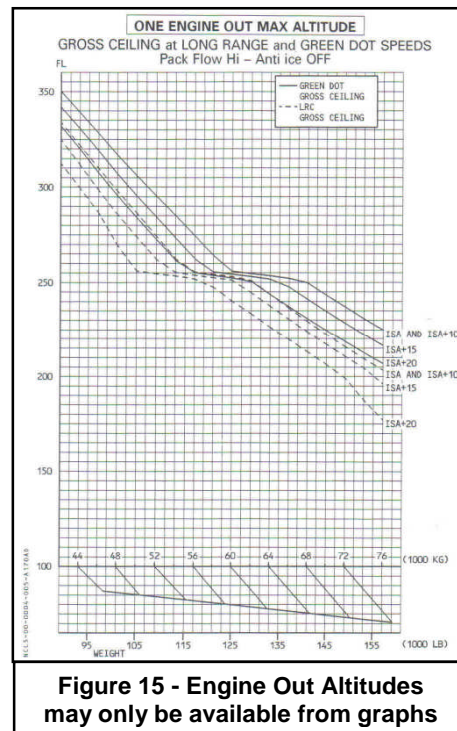
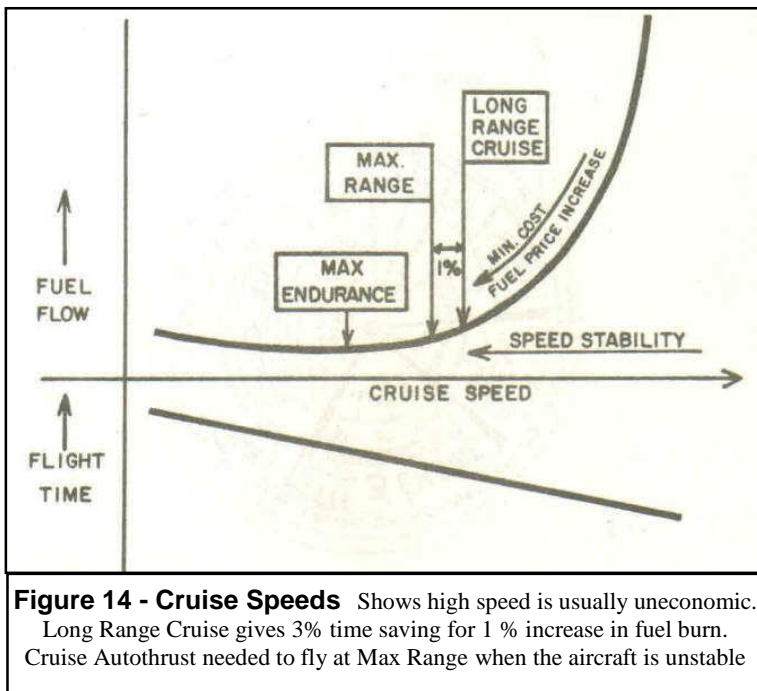


Figure 14 shows the effect of speed on fuel consumption – flying significantly above the normal design cruise speed can be grossly uneconomic. Most airlines operate close to the Long Range Cruise speed which gives about a 3% decrease in flight time for a 1% increase in fuel consumption. Cost Indices, selected by the airline according to the variable costs of the sector, can be inserted into Flight Management Systems to give minimum cost speeds, normally close to LRC.

On payload limited sectors a cruise autothrust can fly the aircraft at Max Range, which is difficult to achieve manually as the aircraft is unstable, this can reduce the fuel required and allow more payload to be carried. However the drag curve is fairly flat around Max Range for most current aircraft and flight time may be increased considerably for little gain in fuel. *Conversely time can be lost by slowing down to increase flight time with NO fuel penalty and avoid circling in holding patterns close to the airport which wastes the fuel while holding* – see below.

Crews should have a general knowledge of the performance of their aircraft such as:

All engines Maximum and Optimum Altitudes (provided by the FMS) **and whether limited by engine thrust or airframe buffet** (not shown in the FMS).

Engine Out altitude and how it relates to the Minimum Safe Altitude over terrain - **rather than relying on the FMS, where Engine Out altitudes may only be available after an engine has failed/been shut down**, or obtained from graphs which are difficult to read quickly which may be needed if the FMS has failed as in Figure 15.

Crews have climbed the latest aircraft with modern FMS above the maximum recommended altitude and had to descend again. This has been due to lack of knowledge of aircraft performance, the effects of temperature, operation close to “coffin corner” when limited by airframe buffet, incorrect weight entered into the FMS, etc. **In some cases this has led to an upset and loss of control.**

Figure 15 shows tables giving comprehensive performance for 2 different aircraft types – a B747 Freighter and an A320. All engines maximum/optimum altitudes, thrust settings and cruise speeds, Engine Out altitudes, etc, are provided. **Should primary instruments such as those providing Mach/airspeed information fail, engine thrust settings are readily available to keep control in level flight** while maintaining the normal aircraft cruise pitch attitude of 3°. This data is not readily available from the FMS even if available.

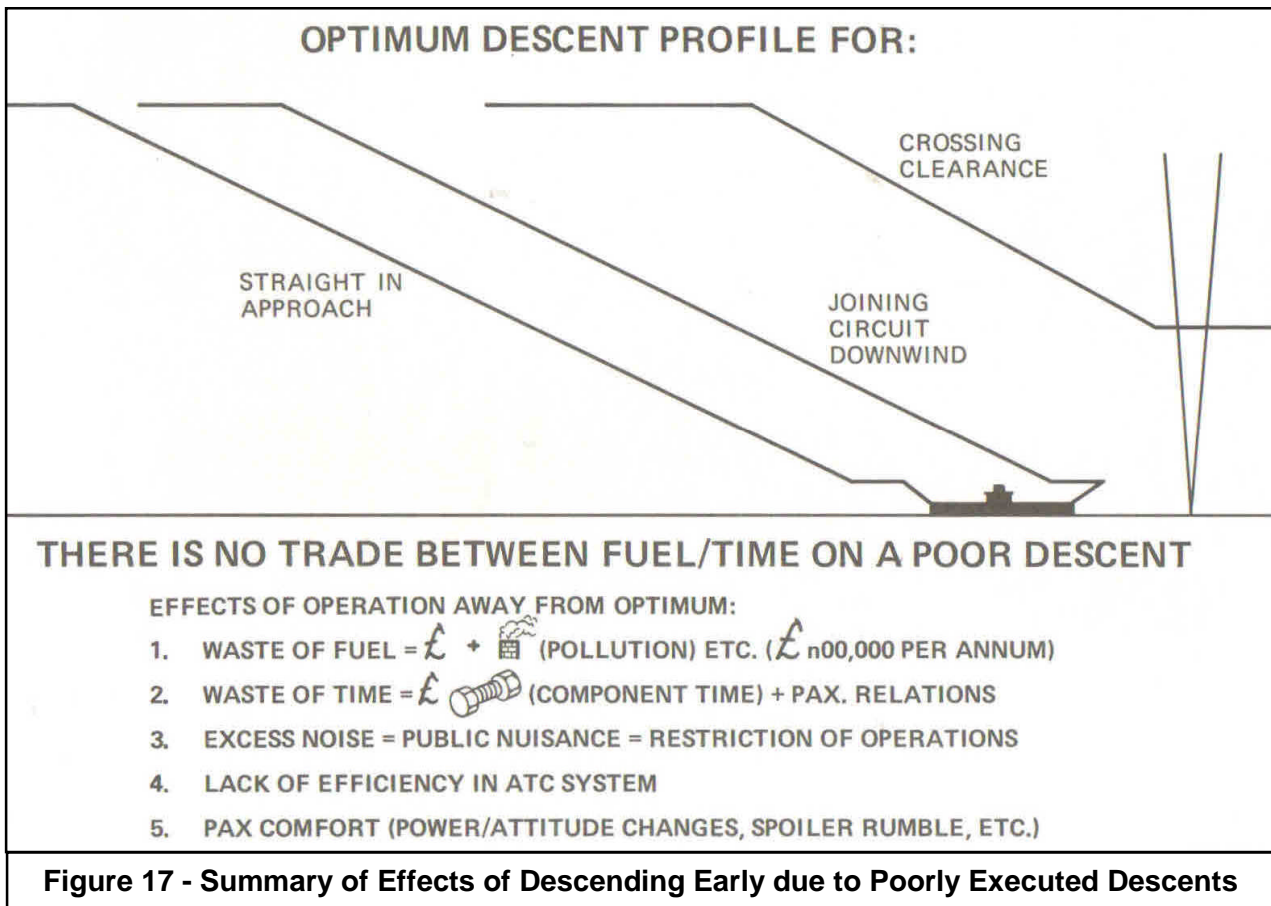
Fuel can be Saved by Slowing Down Early to Avoid Holding Delays Waiting to Land

In North America, Australasia and in some parts of Europe such as Scandinavia aircraft are normally given speeds to fly well before arrival so traffic is coordinated into the approach and landing sequence without any need for holding delays.

However in some European areas due to restricted liaison between ATC centres, aircraft are not given advanced warning of any holding delays and continue flying at normal speeds to then wait in holding patterns. Whereas if prior notice had been given of an Expected Approach Time the aircraft could slow down thus burning minimum fuel to arrive for an immediate landing, and saving most of the fuel wasted by holding.

The FMS fitted to many aircraft are capable of 4D navigation (demonstrated in a Lockheed TriStar test flight in 1976) and can control the aircraft’s speed to arrive at a waypoint at a specific time. **It is disappointing that this facility is not yet being used, and remains an area where considerable amounts of fuel could be saved.**

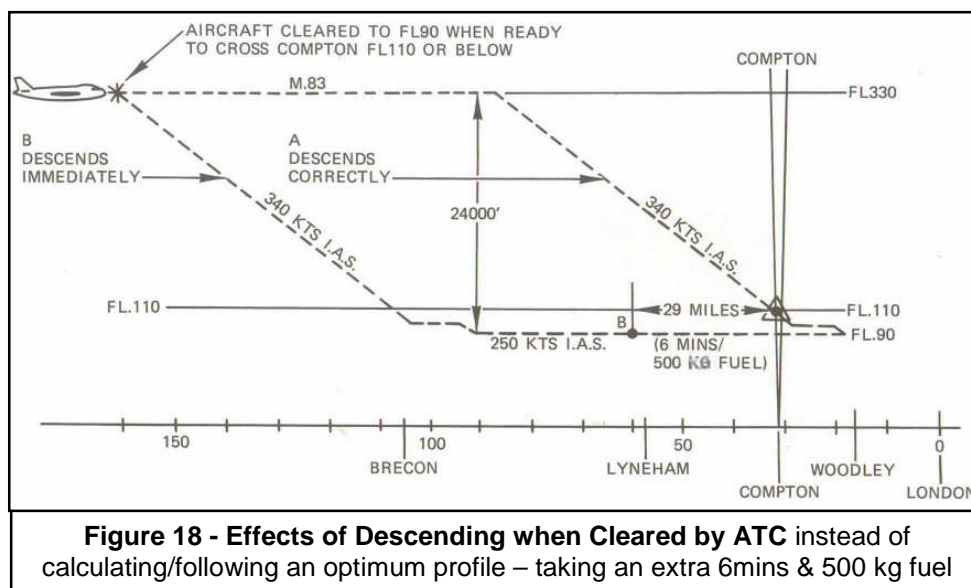
7. DESCENT



The information in Figure 17 was part of an article written in 1973 which indicates that pollution of the environment was then a concern in certain circles. But descent profile management was left to the judgement of the pilots who normally used simple rules of thumb like desired Altitude in 000s ft = 3 x distance to run in nautical miles to compute a descent profile mentally.

To calculate and follow an efficient descent profile to a DME-Altitude crossing clearance uses considerable mental capacity and individual pilot's performance vary significantly. Those operating in environments with low traffic where continuous descents to land are normal, uninterrupted by ATC clearances to level off, can be used to computing optimum descents and often the challenge between crews is to close the thrust levers at Top of Descent and open them again at about 1,000ft for the most efficient descent without using speedbrakes to correct any errors.

However some crews who were operating mainly in busy ATC environments could tend to follow ATC instructions and descend immediately when given clearance to a lower level. – the effects are shown in Figure 18 where the flight descending when cleared takes 6 mins longer and burning some 500kg more on a 747.



NASA conducted descent trials on their development B737 using a Flight Management System and compared these with descents profiles flown by aircraft observed by ATC.

The example in Figure 19 shows that a typically flown descent seen by ATC, where the aircraft descended when cleared by ATC then increased thrust to fly level at the cleared altitude, consumed 655lbs of fuel compared with 447lbs by the NASA B737 which descended later and slower with idle thrust but still took the same flight time.

Several hand held devices were created to help pilots to establish and follow more efficient descent profiles than most pilots could achieve mentally. The most practical example is shown in Figure 20 which sets up an idle descent from cruise altitude on a gradient of 400 ft per nautical mile, an 8 nm deceleration to 250kts at 10,000ft and then a gradient of 300ft/nm which can lead into a normal 3° final approach. The speeds achieved with idle thrust depend on aircraft type and weight and wind component - for a B747 at landing weight speed would be about Mach.84/340kts above 10,000ft which in average winds would be close to the profile computed by an FMS.

Rate of Descent is set up according to groundspeed and the profile could be easily followed within a few hundred feet by regular DME-Altitude checks which could be read directly as shown in Figure 20.

In comparison mental computation to check progress along a simple, less efficient, 300ft per mile profile would require the regular calculation:

Altitude=(DME-23-8)x300+8,000. eg at 50 DME:-
50-23-8=19x300=5700+8000=13,700ft.

If a crew made these regular crosschecks the mental capacity involved would detract from other monitoring functions.

This computer was nearly ordered by United Airlines as it worked well for 747s and DC10s but was too steep for DC8s and too shallow for 727s.

(If more time had been available to demonstrate to United the benefits of the 3° Glideslope computer on the reverse of the Descent Computer, shown in Figure 29, United might have been persuaded to adopt Constant Angle rather than Step Down Non Precision Approaches which contributed to the highest accident rate in the next 30 years, as shown in Figures 42-46.)

BOAC put 2 computers on each of their aircraft to encourage crews to manage their descents as efficiently as possible. In a survey BOAC B747 pilots agreed that their descent efficiency was improved by at least 10 nm when using the computer, which would cover the cost of the 2 computers in one descent.

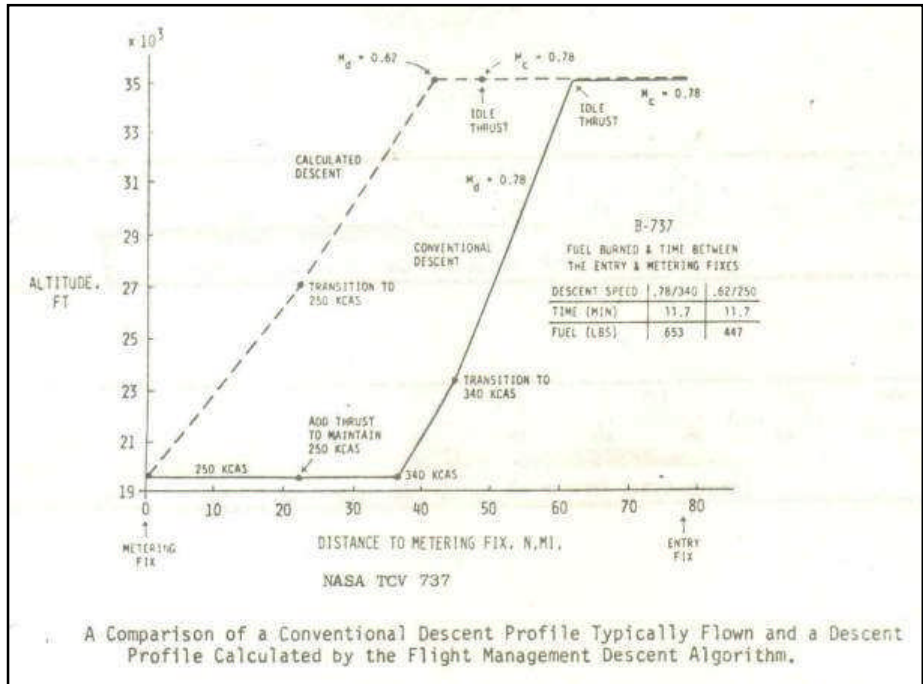


Figure 19 - NASA B737 Descent Trials – Typically flown early descent flying level at low altitude burnt 46% more fuel than later idle descent

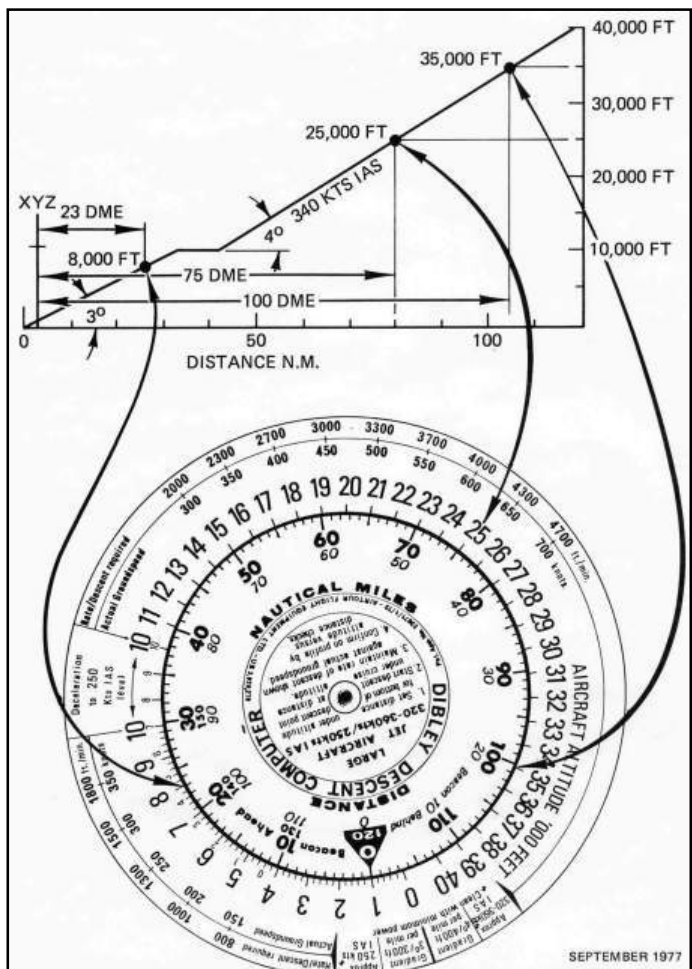


Figure 20 - Circular Slide Rule Descent Computer
Primarily designed to define a descent profile to comply with DME-Altitude crossing clearance – eg as set to Cross 23 DME XYZ at 8,000ft at 250kts. Descent from FL350 starts at 100DME at 340kts with cross-checks to confirm on profile, decelerating to 250kts at 38DME-10,000ft

The fuel conservation campaign started by BOAC in 1973 following the large fuel price rise in the first fuel crisis helped to keep the company profitable up to 1977 when British Airways merged fully to become one company.

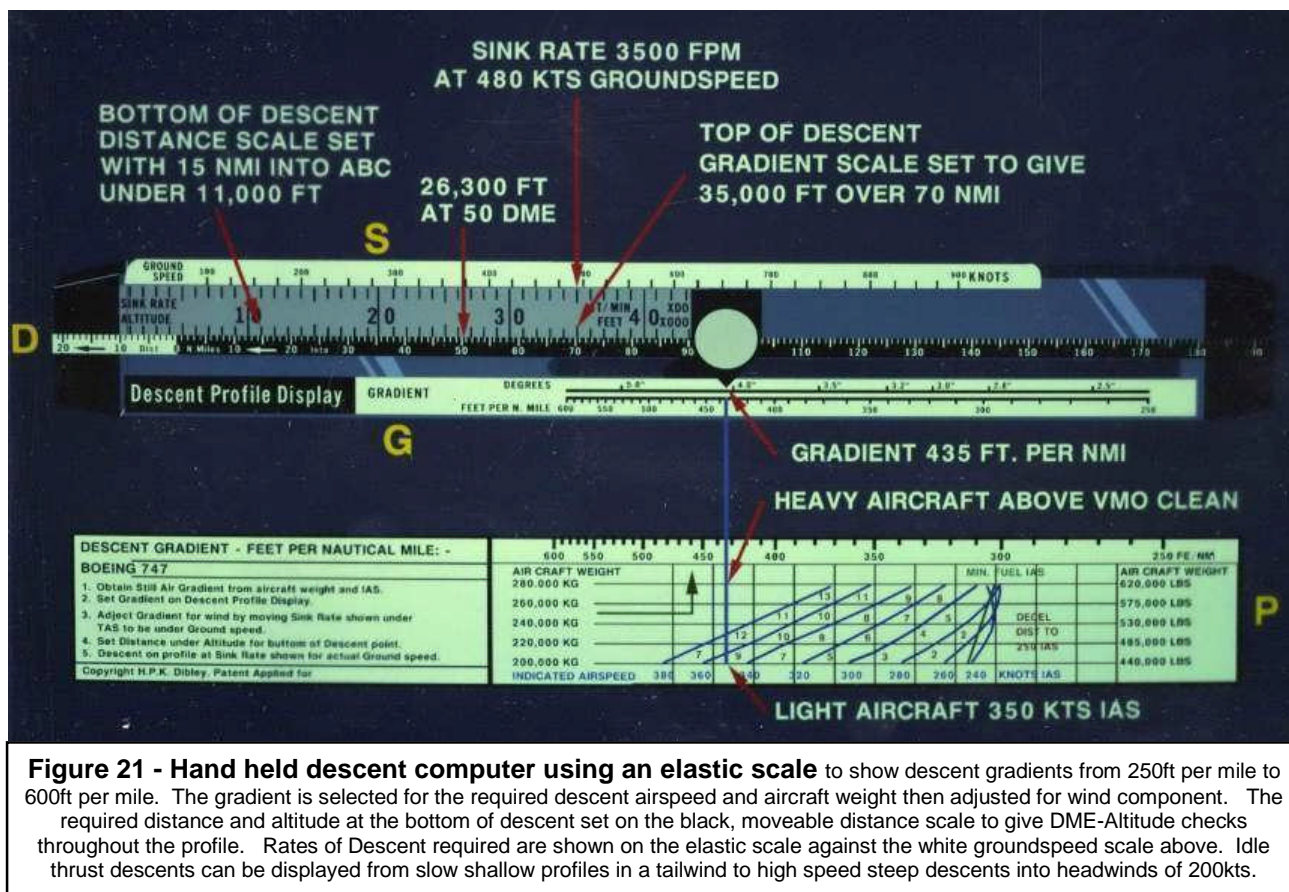


Figure 21 - Hand held descent computer using an elastic scale to show descent gradients from 250ft per mile to 600ft per mile. The gradient is selected for the required descent airspeed and aircraft weight then adjusted for wind component. The required distance and altitude at the bottom of descent set on the black, moveable distance scale to give DME-Altitude checks throughout the profile. Rates of Descent required are shown on the elastic scale against the white groundspeed scale above. Idle thrust descents can be displayed from slow shallow profiles in a tailwind to high speed steep descents into headwinds of 200kts.

The circular descent computer in Figure 20 based on a fixed descent gradient provided efficient idle thrust descents in most circumstances – and certainly avoided the gross errors when some crews relied on mental arithmetic – but the profile was not optimum in extremely high winds and abnormal descent speeds. Figure 21 shows a computer with an elastic scale that could set shallow gradients to cover slow speed descents in a tailwind up to steep high speed descents in winds up to 200kts.

The device was used successfully on classic B747s and could provide smoother descents than the automatics on the Airbus A340, but on normal passenger flights (rather than on VVIP flights where smoothness is paramount) the extra workload was not worthwhile for the reduction in changes in engine thrust/noise that could be selected by the FMS.

Aircraft Flight Management Systems now fly very efficient descent provided the correct variable data such as winds is inserted. However changing waypoints can be time consuming requiring too much heads down time at a critical period of the flight and if vectored away from the planned route during descent the crew can be back computing the best profile by mental arithmetic.

8. APPROACH

The initial approach phase of a flight contains the transition from the end of descent to the final approach to land when the crew complete their checks to confirm that everything is ready for the arrival and configures the aircraft by selecting flaps as the aircraft is required to fly slower.

With no ATC delays this may be a short period while continuing to descend towards the final part of the approach about 5-10 miles from the runway, but in busy airports Air Traffic Controllers may have to vector the aircraft on headings and speeds for many miles to be integrated with other aircraft on to the final approach path to the runway. (Systems are being developed to assist controllers and perhaps share the workload with the aircraft crews as described below.)

If a busy airport is surrounded by urban areas this approach phase of the flight can be most critical time in terms of creating unnecessary aircraft noise and extra fuel burn, being determined by the altitude assigned by ATC and the aircraft flap and gear configuration selected by the crew.

The altitude over most entry points used by ATC from which they feed aircraft into the approach sequence to the runway centreline is normally between 5,000 and 10,000ft and the distance is about 20 to 60 n miles to the airfield. The noise perceived on the ground from aircraft flying clean without gear or flaps extended at these altitudes can be similar to normal urban traffic noise and if aircraft can be kept clean as long as possible then the disruption to urban life will be a small. However if ATC requires the aircraft to fly at low altitude and then flaps and gear are extended early by the crew the noise could make conversation on the ground impossible especially from older turbojet aircraft.

Fuel consumption is also greatly increased by flying level with flaps and gear down as illustrated by Figure 22 which shows the comparative fuel consumption of a jet airliner at different altitudes and in various configurations with flaps and/or gear extended when flying level or when descending.

The baseline is an aircraft flying at FL370/37,000ft and Long Range Cruise speed of M.83/270kts Indicated Air Speed.

Minimum fuel is burnt while descending clean, which shows that long relatively slow descents are the most fuel efficient. High speed descents, whether with idle thrust having spent longer at cruise altitude or by descending earlier with thrust applied to achieve the higher speed, which may be necessary to save time, burn more fuel.

When having to fly at lower levels the fuel penalty is minimised by flying clean at the correct speed to achieve the optimum aircraft attitude/angle of attack. Fuel flow can be similar to that at cruise altitude but as the True Air Speed is reduced so the fuel consumption per nautical mile flown is increased.

The highest fuel consumption is when flying with flaps and gear extended – some 400% more than cruise consumption in this example (over 500% on a B747) – which also makes the loudest noise over the ground.

On the final part of the approach if descending on the glideslope to the runway with the gear up and approach flap the fuel consumption is slightly less than the baseline in the cruise, and with the gear down and full landing flap it is less than flying level with the gear down and approach flap.

It is evident that to minimise noise disturbance after leaving the entry point during the initial approach, that level flight should be resisted if possible and flying level with gear and flaps extended should be avoided at all costs.

Figure 23 shows an estimation of the noise disturbance of aircraft flying into London Heathrow airport. The standard approach procedure recommended by manufacturers and used by most companies was to start extending the landing gear just before intercepting final glideslope to the runway, then extend landing flap and complete the Landing Checklist.

The aircraft does not fly level with the gear down, and as the aircraft starts to descend while the gear is extending the thrust required should remain fairly constant avoiding large thrust changes which can be disturbing on the ground and to passengers.

This was not as quiet/fuel efficient as delaying the landing gear until further down the glideslope as suggested in Figure 23 but the procedure had greatly improved safety by avoiding the unstable approaches which caused accidents in early jet operations.

ALTITUDE/CONFIGURATION FUEL BURN COMPARISON (330,000 LB/150,000 KG AIRCRAFT)

ALT:	AIRSPEED NM/TONNE % FROM FL 370	CONFIGURATION	FUEL AND TIME FOR 10 NMS	FUEL AND DISTANCE FOR 1 MIN
FL370	M.83/270 KNS 72 NMS	 LEVEL CLEAN	140 KGS 75 SECS	110 KGS 8 NMS
Baseline Cruising at 37,000ft				
FL100	300 KNS 47 NMS + 150%	 LEVEL CLEAN	210 KGS 105 SECS	120 KGS 6 NMS
FL50	210 KNS 40 NMS + 180%	 LEVEL CLEAN	250 KGS 160 SECS	100 KGS 4 NMS
FL50	210 KNS 31 NMS + 230%	 LEVEL FLAP 40°	320 KGS 160 SECS	120 KGS 4 NMS
FL50	160 KNS 18 NMS + 400%	 LEVEL FLAP 22° GEAR DOWN	550 KGS 220 SECS	150 KGS 3 NMS
Maximum Fuel Consumption				
FL200 DESCENDING	320 KNS 210 NMS - 65%	 DESCENT CLEAN FLIGHT IDLE	50 KGS 85 SECS	33 KGS 7 NMS
Minimum Fuel Consumption				
FL30 DESCENDING	170 KNS 90 NMS - 20%	 3° GLIDESLOPE FLAP 10 FLT IDLE	110 KGS 140 SECS	33 KG 3 NMS
FL30 DESCENDING	150 KNS 20 NMS + 350%	 3° GLIDESLOPE FLAP 42° GEAR DOWN	480 KGS 230 SECS	130 KGS 2.5 NMS

SEPTEMBER 1977

Figure 22 - Comparison of fuel burn in Various Configurations

Baseline is at normal cruise speed M.83/270kts at FL370

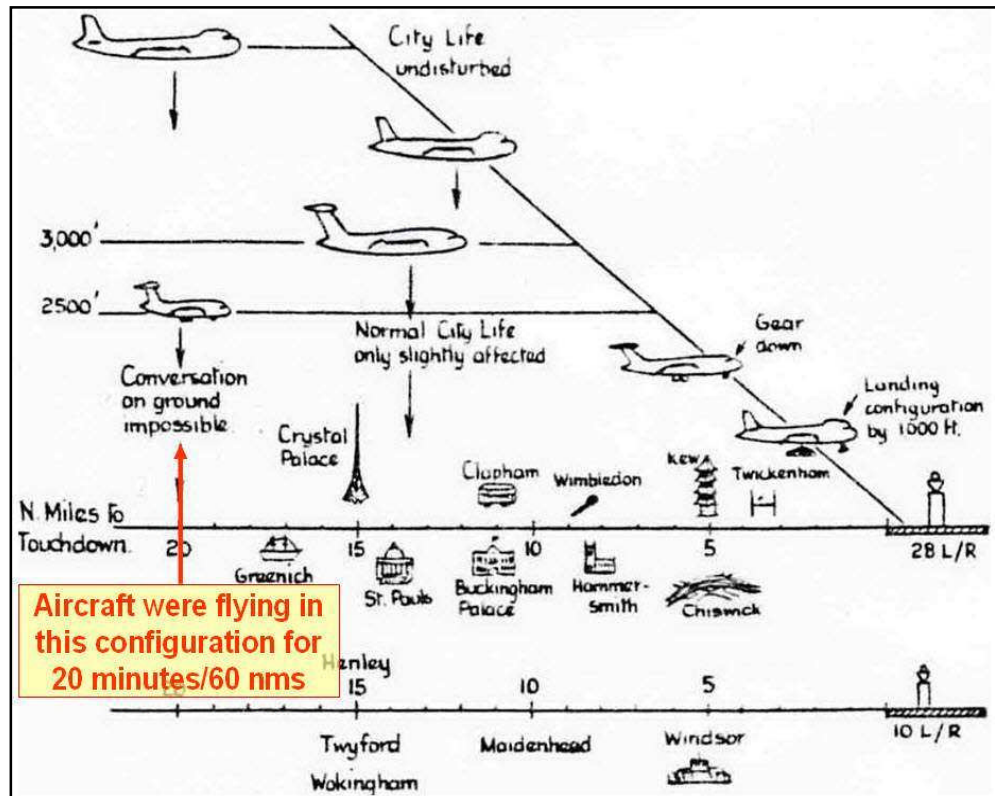
Minimum fuel is burnt during descent from altitude showing that long slow descents are the most fuel efficient.

Fuel burn at low level is minimised when the aircraft is flown clean.

Maximum fuel is burnt flying level with flaps & gear extended.

If the crew did not have information on how far they were from the runway, which was the case in the early 1960s, it could be wise to extend the gear slightly early to make sure the aircraft was sensibly configured before intercepting the glideslope. However one company was more conservative and included gear extension in their initial approach checklist which was normally completed when leaving the entry point/holding fix, which could be 60 n miles from the runway.

The effect of extending the landing gear early meant that the aircraft descended relatively steeply so that the aircraft flew at low level for considerably longer than necessary. The normal routes into Heathrow's Westerly runways over central London are shown in Figure 24.



Aircraft were flying in this configuration for 20 minutes/60 nms

Figure 23 - Aircraft Noise Disturbance at Heights and Configurations
 Maximum noise is created by aircraft flying at low altitude with flaps and landing gear extended. The procedure proposed intercepting the glideslope with the gear up and to minimize noise under the glidepath by delaying gear extension until about 1,500ft above the runway to be properly stabilised in the landing configuration by 1,000ft.

Following the Roskill Commission which chose an inland site for the London's 3rd airport in 1970, largely influenced by the excessive aircraft noise then experienced over central London, this was changed to Maplin Sands well away from urban areas, 100km East of London on Foulness Island on the Essex coast. The decision was eventually made to expand Stansted airport instead and as quieter procedures and less noisy aircraft were introduced the noise over central London was found to be acceptable. (Extending the landing gear early at the entry point was also extremely expensive – 50% more fuel could be burnt on a short flight.)

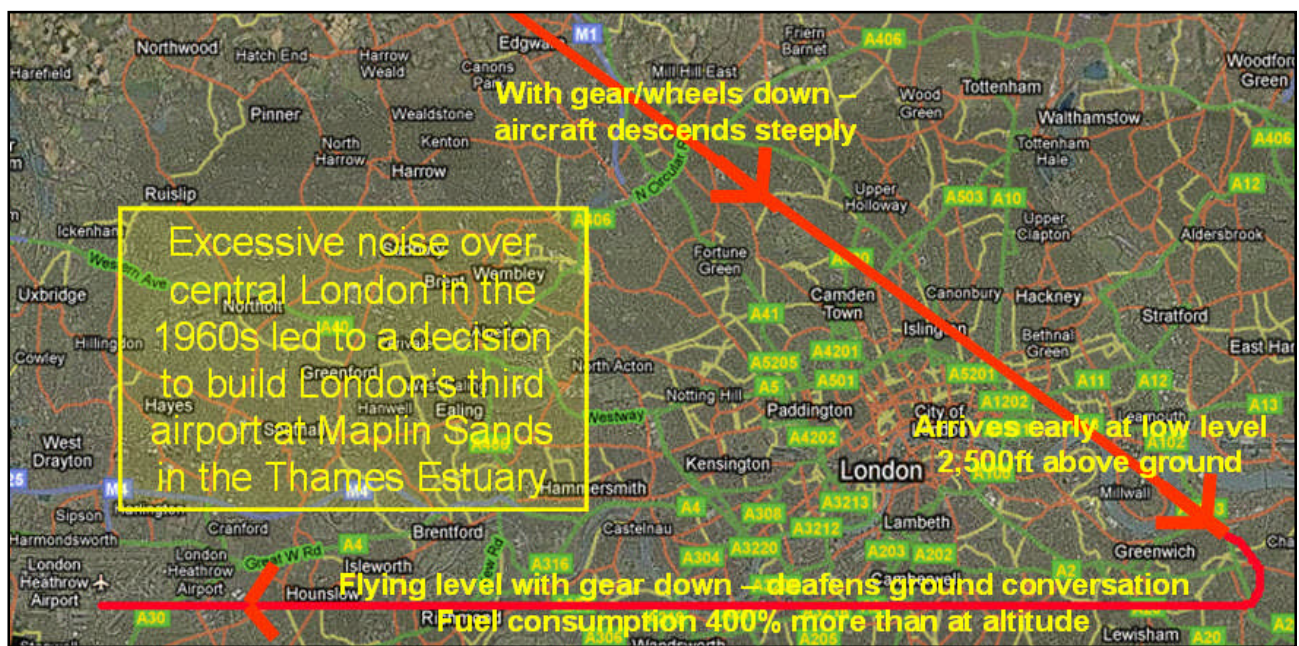


Figure 24 - Effect of Extending Landing Gear during Initial Approach when leaving the Entry Point
 Due to the landing gear's extra drag the aircraft would descend more steeply than aircraft flying "clean" and fly at low level over central London in the noisiest/most uneconomic configuration shown by Figure 22.

To try and reduce the extreme levels of noise over central London an article was published in the Guild of Air Pilots and Air Navigators Journal of March 1974 (see **Appendix A** Page 37) suggesting that crews should be encouraged to plan their descents so that they could ideally fly a continuous descent from the entry point to join the glideslope to the runway, and that in good weather the landing gear should be lowered at about 1,500ft while descending for the aircraft to be stabilised in the landing configuration by 1,000ft as in Figure 23 – which is the normal altitude when flying a visual circuit. DMEs should be added to the runways so that crews should be able to judge their distance to touchdown and thus be able to descend their aircraft at an appropriate sink rate and to configure their aircraft efficiently.

The Head of UK NATS accepted the idea and encouraged by Lufthansa who were asking for similar procedures, Constant Descent Approaches were introduced into LHR in 1975. DMEs were not considered necessary by the department in NATS in charge of radio navigation aids but the UK Department of Trade, then responsible for aircraft noise, paid for DMEs to be installed to assist pilots to fly CDAs and thus reduce noise.

In addition Air Traffic Controllers gave aircraft an estimate of track miles to run to touchdown so crews could assess whether they were close to the ideal 3 degree profile to land, normally by multiplying the distance by 300. ***If all approach controllers were required to pass “estimated track miles to touchdown” as in the UK then crews would be encouraged to control their sink rate to fly a Constant Descent Approach into most airfields world wide.***

CDAs were not implemented as well as hoped. The procedure was published by the CAA and included in the official navigational documentation for the airfield such as those published by providers like Jeppesen but it was largely left to crews to develop their own techniques rather than be given training by their company, although crews flying regularly into LHR naturally became proficient. (Virgin Atlantic has recently started to give such training which is more necessary for a long haul airline operating into UK airfields relatively infrequently.)

Also the procedure has yet to be included in the manufacturers’ training manuals, and the standard published procedure remains to intercept the glideslope from below when flying level at about 3,000ft, rather than flying a constant descent from above 5,000ft to smoothly intercept the glideslope without any period of level flight. Therefore many operators tend to stick to their standard procedures to descend early and fly level.

Very efficient CDAs are operated at night by UPS into Louisville, USA using a system to sequence and merge aircraft shown on Pages 29-30. CDAs have recently been introduced into Los Angeles and Atlanta, however these are more efficient than most of the CDAs in Europe since they ideally start at cruise altitude. CDAs from high altitude to save fuel are possible with the unified ATC system in the USA, but except in less busy areas like Sweden who have started CDAs from cruise altitude, Europe will have to wait a long time for the aims of SESAR (Single European Sky ATM Research) to be realized before such fuel efficiencies can be achieved throughout descent.

However the CDAs as developed in the UK and in the Netherlands shown in Figure 25 starting from about 7,000ft, can still give worthwhile noise reductions to areas from 10 to 25 miles from the runway.

If the manufacturers could approve the procedure in their operating manuals then it could become universally used giving considerable benefit to communities close to airports worldwide.

For example it is possible to fly CDAs on some approaches into airports such as JFK. It was disappointing to see traffic ahead flying to the same runway some 8,000ft below unnecessarily disturbing the local population!

It is encouraging to see in Figure 26 that some regional US airports are recommending CDAs as a standard arrival procedure to reduce noise.

However incidents have occurred in the US when autopilots pitched up to capture a false glideslope at 3,000ft 30 miles from the runway. Why was the aircraft at 3,000ft instead of close to 9,000ft on an optimum profile? Could not the pilot have been allowed to control the flight more efficiently to stay closer to the optimum profile defined by a CDA?

Accidents occurred in similar circumstances - see the TWA 727 CFIT accident on Page 32 into Washington Dulles, when the aircraft descended to 1,670ft at 25 miles from the runway, while the altitude on the optimum profile to minimise fuel and noise would be about 7,000ft.

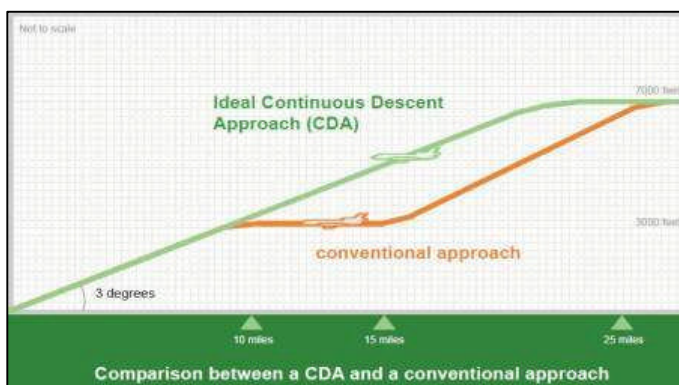


Figure 25 - UK CAA Comparison between a CDA and a Conventional Approach

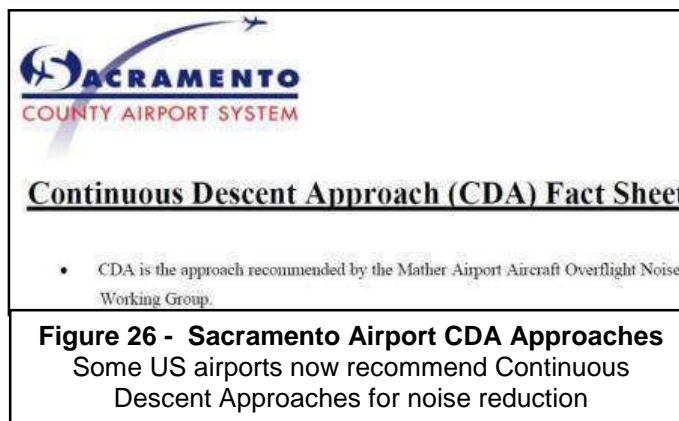


Figure 26 - Sacramento Airport CDA Approaches
Some US airports now recommend Continuous Descent Approaches for noise reduction

9. STEEP APPROACHES TO REDUCE APPROACH NOISE

Approaches on steeper glide paths than the normal 3° glideslope can reduce noise by keeping aircraft higher until closer to the airport. Turboprop and some small jet airliners which can fly these steeper approaches are allowed to operate in to airfields close to the downtown areas in some cities like London City Airport.

Airbus have obtained approval for their smallest aircraft the A318 to fly the 5.5° approach into London City and British Airways are using these types to operate a nonstop service from New York straight into the heart of London’s financial district.

But to fly a steep approach requires extra drag and for the approach the A318 has a switch which changes the flight control laws to extend some speedbrake during the final descent and gives the pilot extra aural warnings when to start the flare to land which is made some 40 feet higher than normal. The autopilot must be disconnected before reaching the minimum altitude when the airfield must be in sight which is higher than for a normal 3° approach, therefore approaches cannot be carried out in weather conditions of low visibility.

While this procedure might be approved for the other small Airbus aircraft in the A320 family, it is not expected to be used by any of the larger wide-bodies – even those now being designed to come into service in the future. Approach engine noise is now relatively low and the advantages of steep approaches for jet aircraft is perhaps becoming less and approach noise reduction is likely to concentrate also on aerodynamic areas such as flaps and the landing gear.

The steep approach into London City airport starts at about 3,000ft so the approach noise beyond about 7 miles can be similar to a normal 3° approach.



Figure 27 - Airbus A318 Modification for Steep 5.5° Approach
For steep approaches on A318s a selection is made to raise spoilers for extra drag and to give early aural warning of the time to flare.

10. CREWS ABILITY TO SAVE FUEL / TIME BY CHOOSING THEIR OWN APPROACHES

Approach tracks into busy airports are normally structured for bad weather and some are flown automatically along an agreed noise routes. Aircraft should be allowed to fly a shorter visual approach when traffic permits as in Figure 28.

In future when traffic permits such tactical approaches might be carried out using the very accurate RNP navigation capability without the need to be visual with the ground.



Figure 28 - Ability to Fly a Visual Approach when able to Save Time and Fuel

Figure 29 - Nairobi Kenya – Main ILS Precision Approach is to Runway 06, after which a 10 minute Backtrack-Taxi is Required to Airport Terminal. DME-Altitude Table on the Left chart allows Non-Precision VOR DME Rwy 24 Approach to be flown on a Constant Angle Approach to the runway of near precision approach accuracy. The Right chart has no table so a Constant Angle Approach cannot be flown.

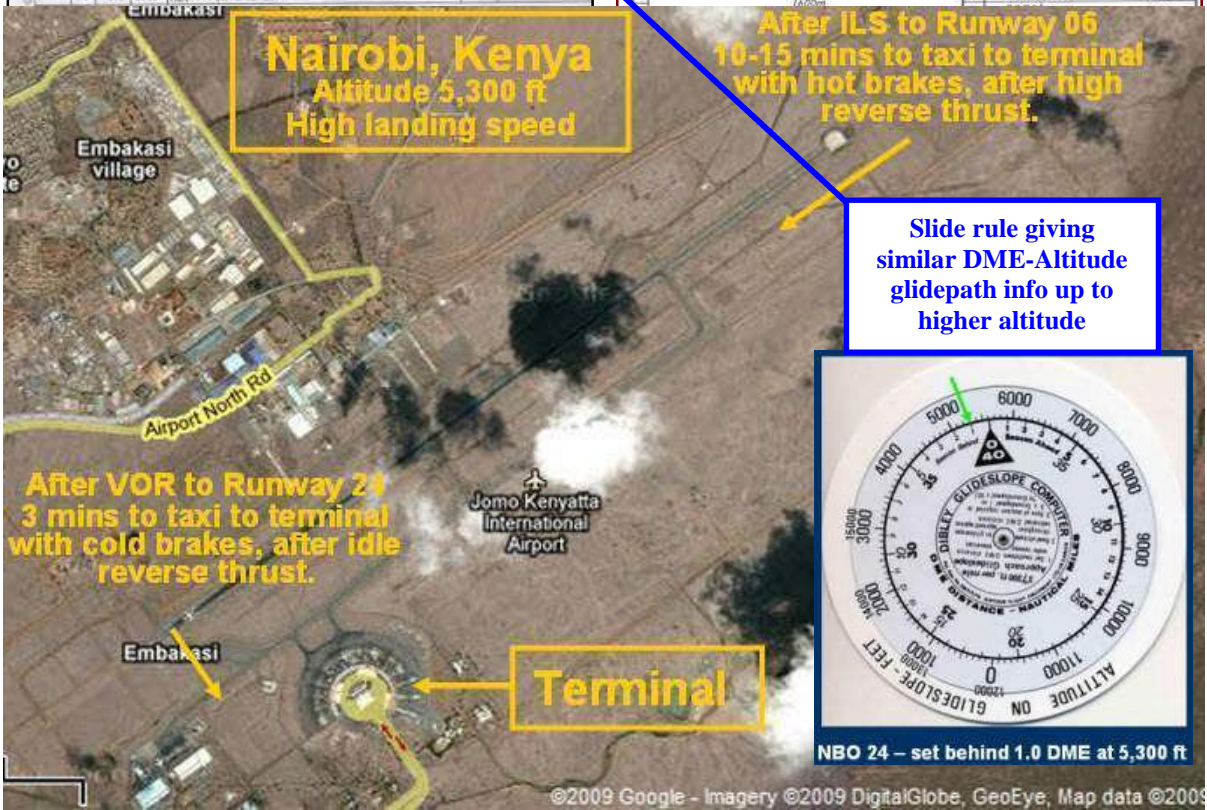
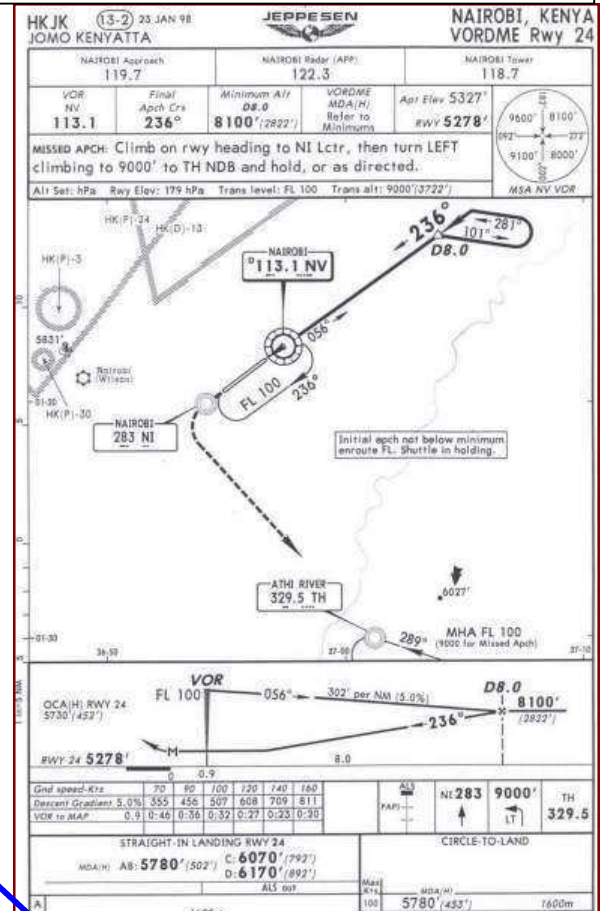
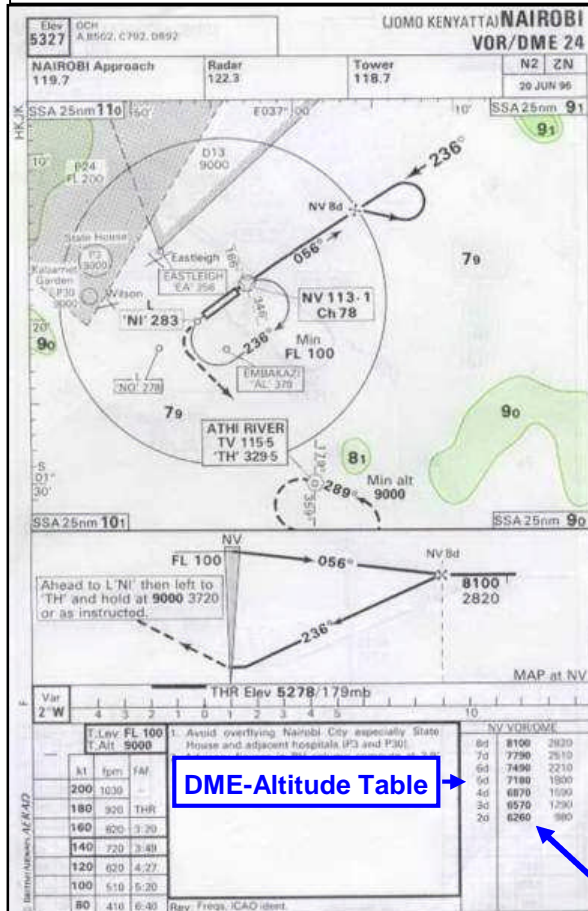


Figure 30 shows a case where considerable time, fuel and brake wear can be saved at Nairobi by using a different runway to usual ILS instrument runway 06 which must be used in poor weather. Runway 06 requires a long taxi back to the terminal, probably with hot brakes, and perhaps having used much reverse thrust to stop before the taxiway back to the terminal.

Using the left hand approach chart with a DME-Altitude table to check the glidepath* on approach, a safe Constant Angle VOR-DME approach to runway 24 can easily be flown to runway 24. The aircraft arrives with cold brakes having used idle reverse thrust thus saving an engine cycle for maintenance after a 3 minute taxi to the terminal.

*or by reference to the circular slide rule Glideslope Computer shown at the bottom right of Figure 29 which also shows the DME-Altitude glidepath, but with the advantage of showing glideslope information from a higher altitude and being able to check the DME-Altitude at any time and not only at the whole nautical miles shown in the chart table.

Operators using the right hand chart without a DME-Altitude glidepath table could not carry out a Constant Angle VOR-DME approach but would have to fly a Step Down “Dive and Drive” approach to descend early and fly level at the minimum altitude until the runway became into sight.

This type of approach has been the cause of many CFIT (Controlled Flight Into Terrain) accidents, many of which could have been avoided if DME-Altitude tables were published on all Non Precision Approach charts when a suitable DME was available, which were published in British Airways Aerad charts from 1975.

Most European airlines’ approach charts included this information but it was not published in many states until after 2000. Jeppesen would not include DME-Altitude tables unless provided by the state authority which, for example, were added for Australia in 2002. Procedures for CDAs were published in New Zealand and India 2005 – over 30 years after VOR-DME CDAs were being flown into Delhi by some operators!

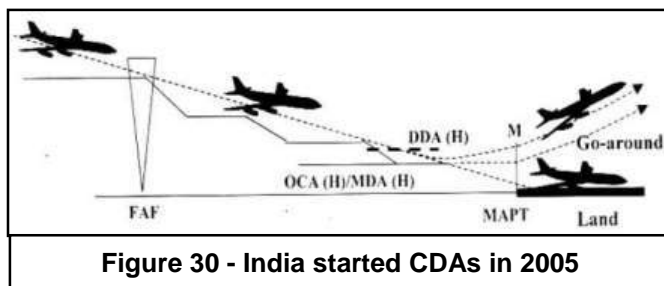


Figure 30 - India started CDAs in 2005

VOR-DME types of Non Precision Approaches are being replaced by GPS based RNP (Required Navigation Performance) approaches which can be flown automatically by the aircraft FMS - see Figure 31. This has caused some states not to implement DME based CDAs, notably the US.

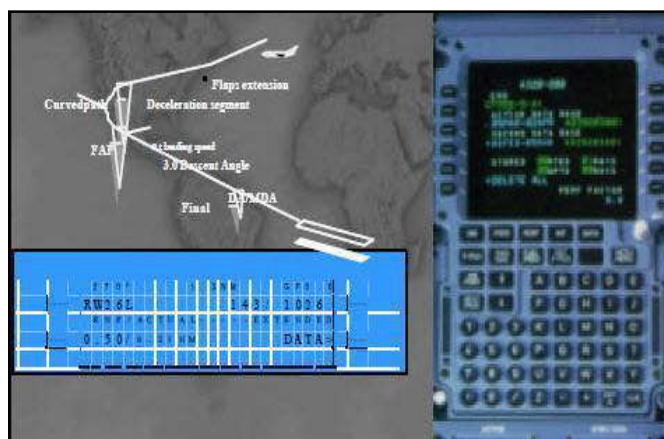


Figure 31 - VOR-DME type Approaches are being replaced by automatically flown GPS RNP Approaches which will take years to implement worldwide, so DME-Altitudes tables will still be required on charts to check the descent profile.

RNP approaches will allow safe CDA approaches to be flown to nearly all runways even in areas of high terrain close to the airfield, except at present in very low visibility requiring an autoland, see Figures 35..

This should provide considerable operational savings as crews should be able to choose the most efficient runway or type of approach, such as runway 24 at Nairobi in Figure 29 or perhaps fly a tactical shorter approach such as in Figure 28 which has previously only been permitted to be flown in visual conditions.

But RNP approaches will take some time to be approved world wide and for all aircraft to be fitted with the necessary equipment – many aircraft will never be fitted. Therefore charts showing DME based CDAs will be required well into the future.

If an aircraft fleet is fully RNP equipped and thus DME information is redundant, a Distance to Runway-Altitude table should be provided so the glidepath can be verified throughout the approach and not at single targets which might be missed due to crew workload, eg radio frequency changes, etc.

11. PAST EXAMPLES OF FUEL SAVED OPERATIONALLY

How much fuel can be saved by improved operations on a typical sector depends of course on the current efficiency of the operator.

In the 1970s some Flight Management Systems manufacturers claimed they could save 10% in fuel burn by flying the aircraft at optimum speeds and altitudes and fly efficient descents, which would justify a very expensive system. However such savings had probably been made by operators who had not refined their procedures with the increased price of fuel by providing crews with the optimum speeds and altitudes they could fly manually – as in the performance tables in Figure 16, instead of using the simpler fixed speeds initially supplied by the manufacturer and not giving crews any form of guidance to fly efficient descents. A fuel saving of 3% percent by an FMS was more realistic for an operator which had optimised its operation but an FMS was still definitely economically justified.

A good starting point for a fuel economy campaign to improve an operation which is suspected not to be as efficient as possible is to list all segments of the flight and show to crews the penalties for operating away from the optimum. Then give crews the information and encouragement to operate the aircraft as best they can.

In the example below the total possible saving from what was assessed to be a normal operation by some crews was 26%, but the excesses were unlikely to have occurred on every sector and all the potential savings may not be fulfilled so perhaps a 5% saving might be realistic.

Subsequent fuel monitoring showed that the crews' saving was 8% immediately the penalties had been highlighted and improved procedures introduced to which they responded well.

(A reminder that one engine manufacturer today spends £800,000,000 per year to improve fuel consumption by 1%).

This could well mean the difference between a profit and a loss to a company in times of high fuel prices.

Items shown in italics are those which may be targets for improvement still today:

Official departure procedures in some European states, eg still specify climb to 3,000ft before acceleration.

*In some ATC systems such as in the UK it can still be advantageous to continue at high speed to the arrival holding point to establish position in the sequence for landing, instead of each aircraft being given an Expected Approach Time to leave the hold and be able to slow down and arrive at the EAT and save the fuel spent in the holding pattern **This could be implemented immediately for aircraft arriving from the West using the 4D facility now available in many Flight Management Systems.***

As Constant Descent Approaches are not in the manufacturers' operations manuals many foreign aircraft follow their standard procedure into CDA airfields such as LHR to fly level before intercepting the glideslope and perhaps extend the gear early.

EXAMPLE OF POSSIBLE EXTRA FUEL BURN ON A 400 NM SECTOR

Flight Plan for Planned Landing Weight (142,000 kgs) 100 nm Alternate (eg Cardiff for LHR): Fuel Required 18000 kgs (Burn Off 8800 kgs) TOW 152,000 kgs. Fuel burn including Taxi - 9600 kgs. (£1440.00)

Fuel Calculated for Max Landing Weight (162,000 kgs), 300 nm Alternate (eg PIK for LHR) Fuel Required 23,000 kgs.

Fuel carried 28,000 kgs Actual TOW 162,000 kgs.

	Extra Burn	Cost	%Increase
Extra fuel carried (10,000 kgs)	300 kgs	£45.00	3.1%
Engines started 2 mins early vice during push back	150 kgs	£22.50	1.6%
<i>Aircraft climbed to 3000 ft with flap, vice cleaning up at 1000 ft*</i>	200 kgs	£30.00	2.1%
Climb Speed 350 Kt vice 300 Kt IAS	150 kgs	£22.50	1.6%
Cruise FL 280 vice FL 350	500 kgs	£75.00	5.2%
.85/340 Kt cruise vice .73/290 Kt Long Range Cruise (4 mins difference)	400 kgs	£60.00	4.1%
Not seeking direct routings (8nm saving)	100 kgs	£15.00	1.0%
<i>Late High Speed Descent arriving at LAM level 10 nms early**</i>	200 kgs	£30.00	2.1%
Flap 4 ⁰ (droop only) selected at 240 Kt vice flying clean as long as possible. (Minimum Manoeuvre Speed V ref + 70 = 205 Kts)	100 kgs	£15.00	1.0%
1 hold with 4' flap vice clean	100 kgs	£15.00	1.0%
30 nms Intermediate approach at 210 Kts with 4 ⁰ Flap vice clean	200 kgs	£30.00	2.1%
<i>Flap 22⁰ and Gear selected 5 nms early**</i>	150 kgs	£22.50	1.6%
One engine not shut down during taxi	50 kgs	£7.50	.5%
* Still the required departure procedure in some states today			
** Still frequently seen in current operations	2500 kgs	£375.00	26.0%

Examples Where Fuel Conservation has – Confirmed a Flight Crew Contract and Secured a Company’s Future

Crewing Contract Secured

An airline which had surplus crews was given a contract to operate one short route to Southern Africa for an airline operating out of the Southern Indian Ocean, while crews from a second airline were flying the rest of their route to Europe and India.

After analysing the relative fuel consumptions between the two sets of crews, it was proposed that if all routes were taken over from the second airline that the fuel savings of about 10% would be of considerable financial benefit to the airline.

In the event the airline agreed that the crews were saving 13% of fuel burn which was more than the cost of the crews and the contract to operate all routes was secured for several years.

Cargo Airline’s Profitability Turned Around

A cargo airline operating two Boeing 747s was facing bankruptcy and new management had been sent in with a view to winding it up. Amongst other cost reduction measures, a fuel conservation programme was instigated. Revenue was also increased on long payload limited sectors by reducing reserve fuel by using en-route alternate airfields. As a result of these measures the company became profitable.

Crews were encouraged check their progress in a fuel monitoring programme. This was strictly non penalising – the crews always made the decision on how much fuel to carry – and non competitive and the identities were not published. (Many airlines run similar programmes.)

Figure 32 shows crews’ average cost per sector over the basic fuel flight plan, both in terms of extra fuel uplifted and extra fuel burnt in flight, taken over 1 year’s operation.

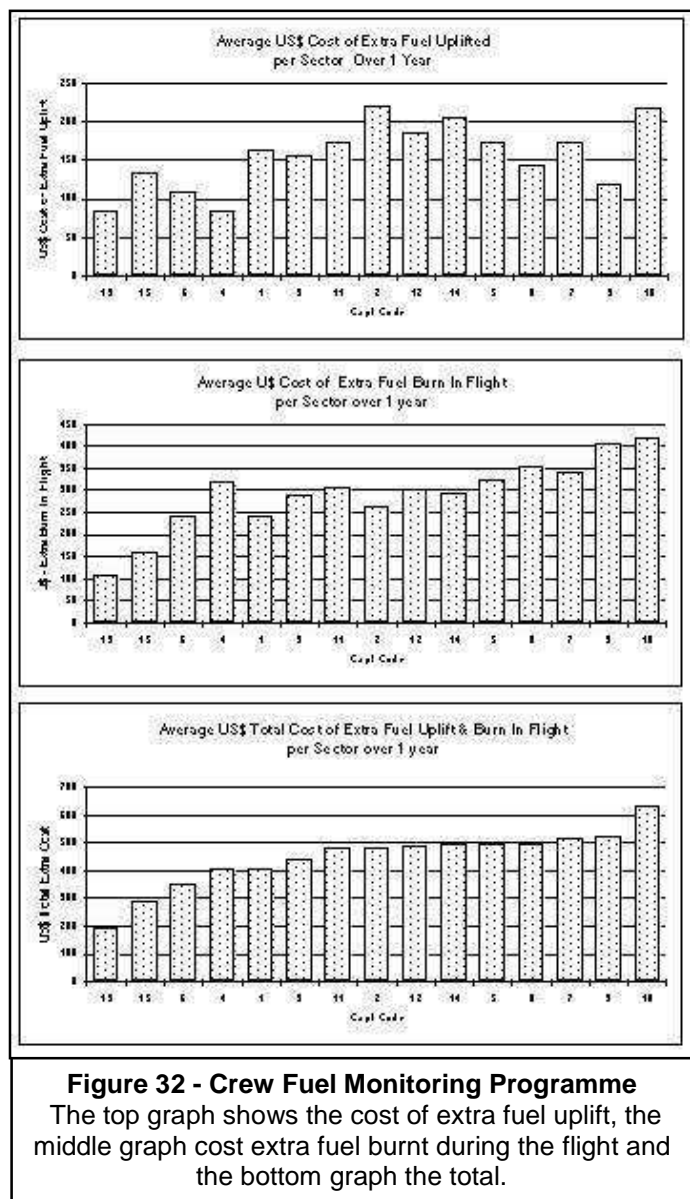
The top graph shows the cost of uplifting extra fuel over the basic flight plan according the Fuel Price Differential as in Figure 5.

The basic flight plan uses normal fuel reserves including diversion to the company preferred alternate airfield, and there may be times when carriage of extra fuel is sensible but such occasions should be relatively rare given a good flight planning system. It is the crew’s absolute right to decide the amount of fuel to be carried.

The centre graph shows the cost of extra fuel burnt in flight over the basic flight plan. More fuel than flight plan can be burnt due an inability to fly at the planned/optimum altitude, ATC delays, stronger headwinds than forecast, heavier aircraft weight than planned (possible if cargo is heavier than declared), poor aircraft performance (which should be compensated for in the flight plan), but averaged over a period crews should be able to burn a similar amount to the plan.

The bottom graph shows the total costs which indicates that the difference between the extremes is over U\$400 per sector, which over a year could easily run into U\$100Ks.

Such information must obviously be used with extreme sensitivity and used only for encouragement. This example does show the value of educating crews to operate as efficiently as possible.



12. POSSIBLE FUTURE OPERATIONAL FUEL SAVINGS

IATA estimates that ATM (Air Traffic Management) enhancements could improve fuel efficiency and CO₂ emissions by up to 12% and that operational improvements could provide a 6% overall fuel saving.

Improved on board systems should allow crews to fly the aircraft as efficiently as possible thereby avoiding some of the gross errors experienced in the past. Indeed a decelerating approach while descending on the glidepath is now the Standard Operating Procedure on Airbus aircraft – but the operations manual still shows the glideslope being intercepted from below while flying level rather than in a continuous descent from altitude.

However it is evident that there are still areas where crews are not cooperating with ATC to optimise their operation whenever possible – eg not descending at the optimum point but earlier when cleared to descend by ATC, asking for a more efficient speed to fly clean/without flaps on approach, etc.

In November 2009 a Scandinavian operator demonstrated to Flight International on an A320 flight simulator comparative savings of 18.4% by operating a 25 minute leg sector largely according to the procedures described in this paper. Therefore, similar to the point made in Section 11 about the early claims made by FMS manufacturers, the “inefficient” base sector must have contained some unusually large gross operational errors, route reductions, etc. The example of an inefficient leg in Section 11 showed potential savings of 26%, but most of these should now be covered by basic use of the A320 FMGC and a sensible company fuel/operating policy.

The landing gear and flaps were extended during the approach to be stabilised by 500ft above the runway which is acceptable in good weather whereas most companies aim for stabilisation at 1,000ft which is required in poor weather when the runway will not be seen until shortly before landing.

On Airbus aircraft the landing gear can be extended after landing flap has been set (on previous aircraft a warning would be triggered if a landing flap setting was selected before the landing gear to prevent gear up landings). Therefore the aircraft could be stabilised with landing flap and the gear selected at about 800ft rather than 1,500-2,000ft which would cause a small reduction in fuel burn and noise, but this procedure is not (yet) in the Airbus operations manuals.

A single engine taxi out used on this exercise and starting the second engine just prior to takeoff could save a significant percentage of fuel burn on a short sector with long takeoff delays and was practised by some Lockheed TriStar operators in the past. Most airlines do not currently use this procedure due to the danger of blast damage when taxiing out from congested areas at takeoff weights, but could safely be used by aircraft at light weights after being pushed back or starting well clear of the terminal for a long taxi out. On longhaul aircraft at high weights it has been routine to taxi out on all engines and then shut down 1 or 2 engines if faced with takeoff delay of perhaps up to 3 hours as experienced at airports such as JFK, New York.

But whereas crews should be able to operate their aircraft efficiently when free to do so without ATC constraints, the large forecast increase in air traffic will mean future fuel savings will primarily depend upon the efficiency of the Air Traffic Management Systems.

ATM systems being developed by the European SESAR (Single European Sky Airtraffic Research) and the US NextGen project along similar lines will incorporate:

- Aircraft fitted with high accuracy RNP (Required Navigation Performance) equipment which also monitors the accuracy of the aircraft navigation system and alerts if downgraded.
- Sharing of all navigational data between the “actors”/stakeholders in the system – airline operations control, aircraft, Air Navigation Service Providers, airports, etc, which are all connected via a system such as SWIM describe below – enabling aircraft trajectories to be coordinated efficiently by controllers on the ground and crews in the air.
- Display of other aircraft in the cockpit so crews can share the air traffic separation workload with the controller and participate in ASAS (Airborne Separation Assistance Systems) such as self separation or following other aircraft in trail.
- An Arrival MANagement (AMAN) system to sequence and merge aircraft by giving a Controlled Time of Arrival to bring aircraft from cruise altitude in an efficient constant idle thrust descent to a smoothly spaced landing flow to the runway.

It is beyond the scope of this paper to discuss the future systems that are likely to form a world wide future Air Traffic Management system in detail – more information from presentations by Phil Hogge are available at www.Dibley.eu.com.

An overview of the main items involved in large system shown below together with examples of smaller Air Traffic systems which are already in operation providing efficient descents and sequenced approaches which might be applied in part elsewhere and provide useful savings now.

Figure 33 gives a snapshot of the current US implementation Procedures - metering in descent leads suitably spaced aircraft into GPS based accurate RNP SAAAR (Special Aircraft and Aircrew Authorization Required) approaches.

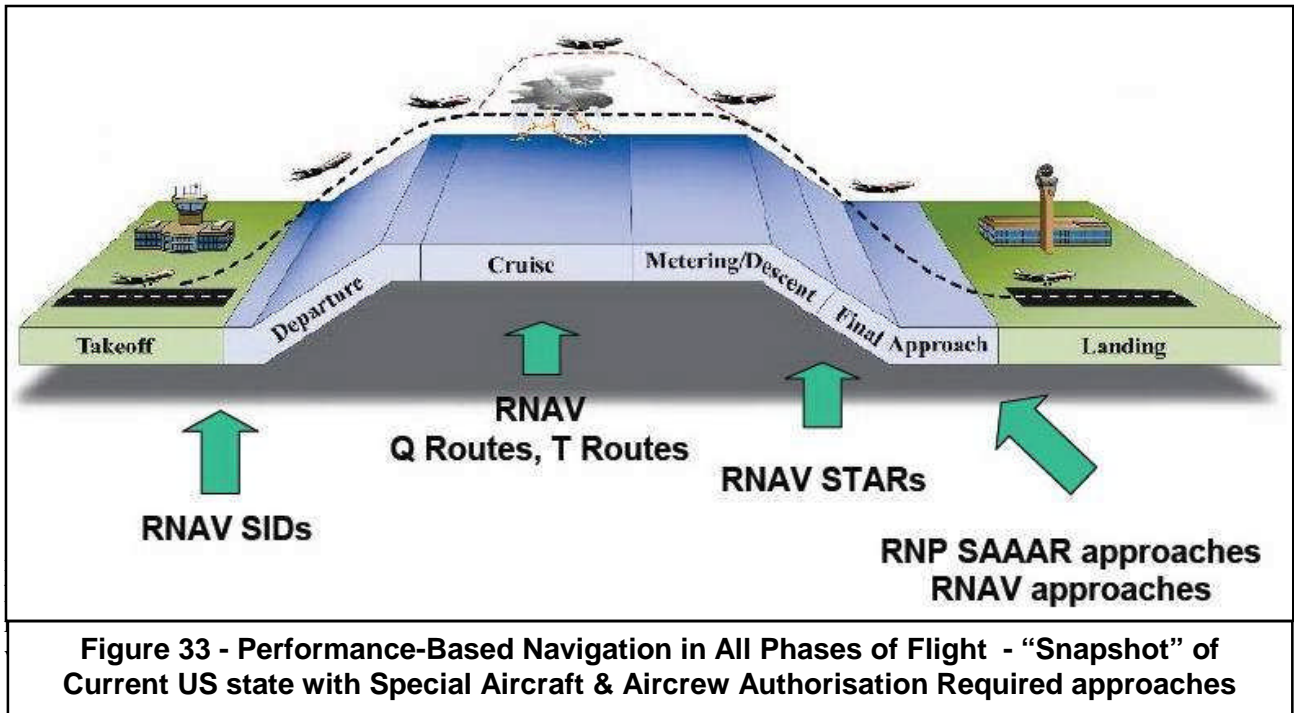
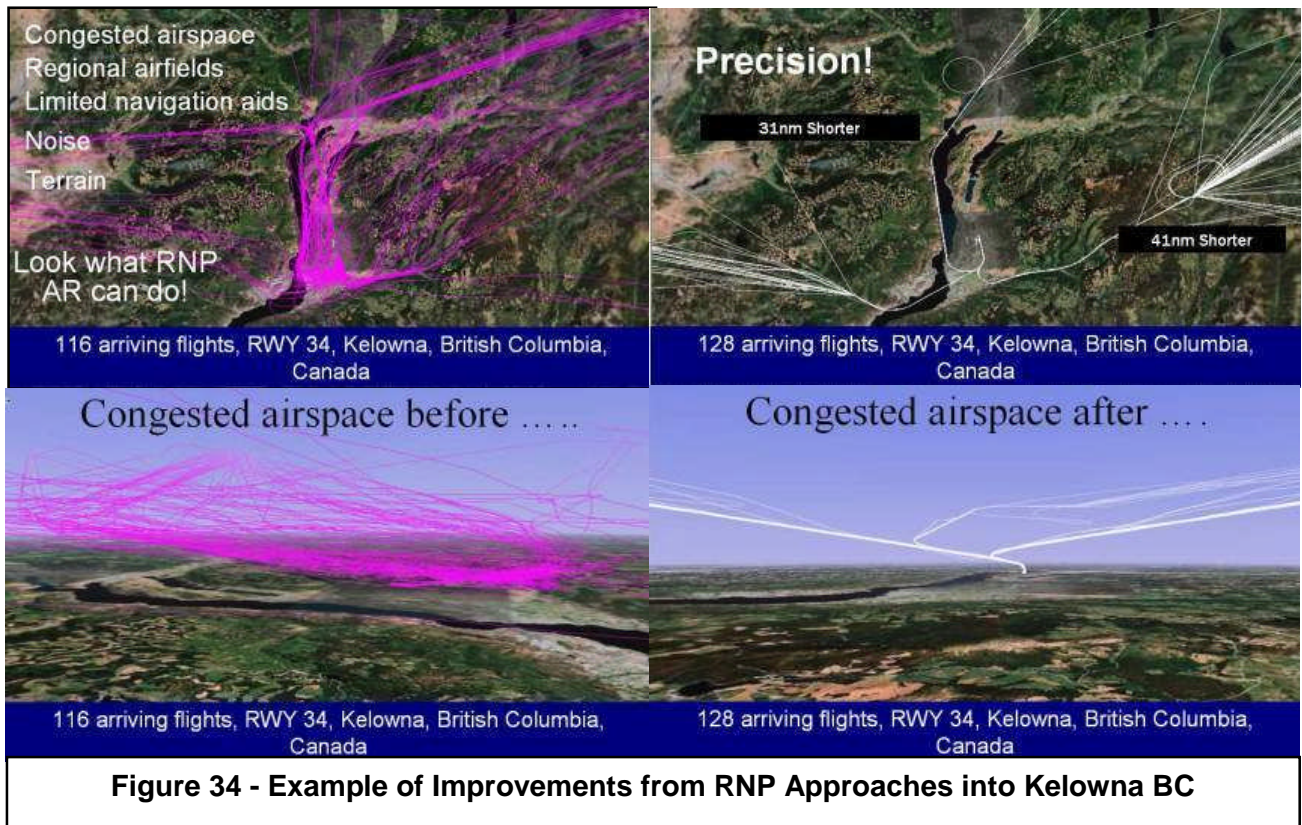


Figure 34 shows the great improvements in navigational accuracy that can be made following implementation of the RNP (Required Navigational Performance) system in aircraft where the routes are being flown with great precision..

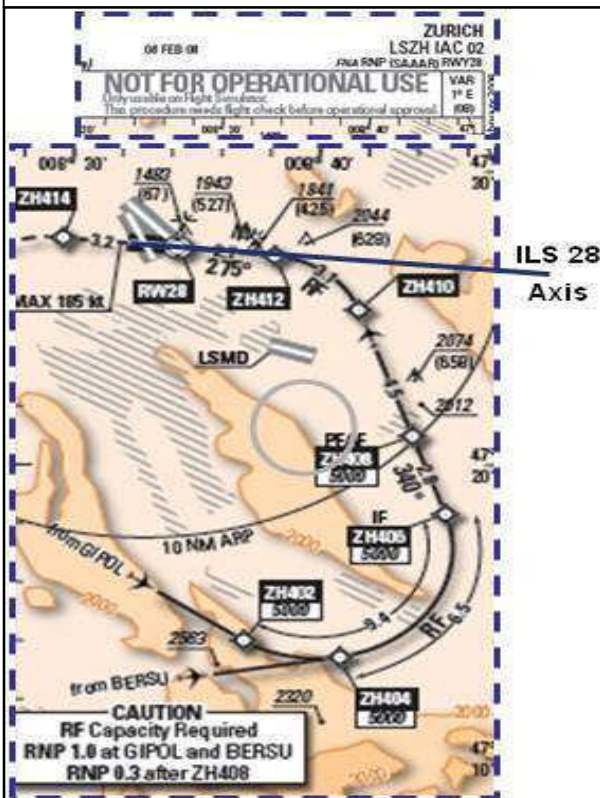
This greater accuracy can lead to reduction in separation standards and thus for more traffic to be carried with greater efficiency including a reduction in route mileage and more optimum climb and descent profiles. **However the full benefits of RNP will not be achieved until the route structure is reorganised to take advantage of the improved accuracy and reduced separation.**



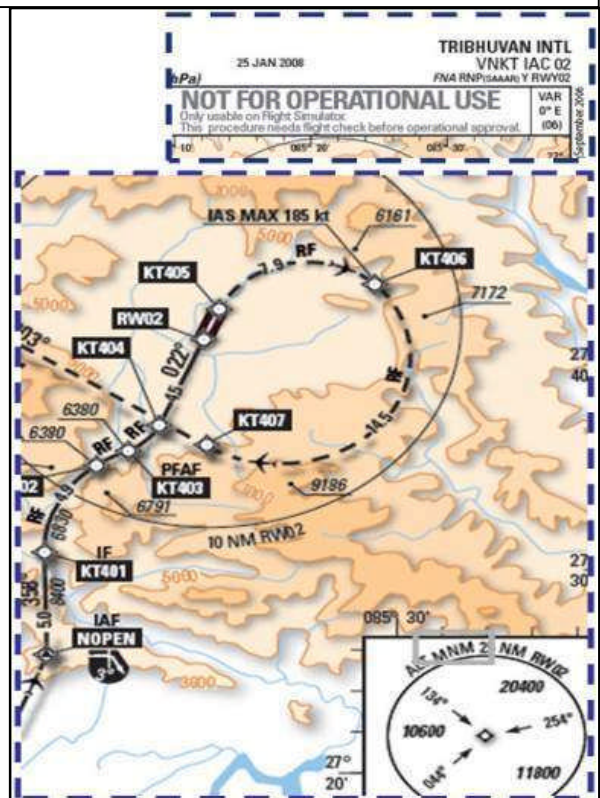
In periods of light traffic when aircraft are not required to adhere to specific tracks for approach sequencing, crews should be permitted to reduce route mileage by flying what they judge to be the most efficient approach under the circumstances.

The improved accuracy of RNP systems will also improve the safety/efficiency of individual aircraft by allowing instrument approaches to all runways in poor weather and eliminating the need for Non Precision Approaches which have proved to be less safe. Figure 35 shows 3 examples of RNP AR approaches/departures in areas of high terrain.

Figure 35 – Example of RNP AR (Authorisation Required) Approaches and Departures



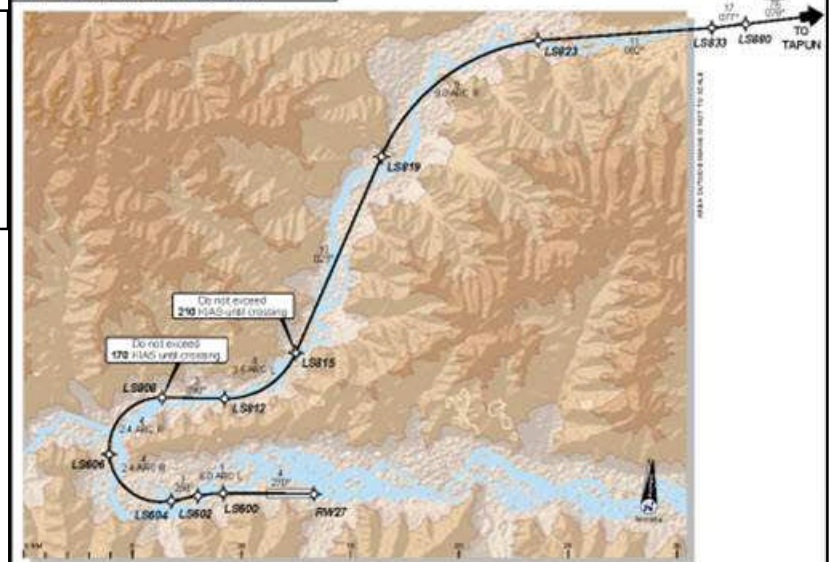
**RNP AR approach to Zurich Runway 28,
Altitude 1,420ft**
Where an RJ100 crashed in 2001 Flying a VOR-DME approach with no DME-Altitude Table.



**RNP AR Approach to Katmandu RW 02,
Altitude 4,390ft**
With steep terrain close to rw so difficult to construct Constant Angle DME-Altitude Table for the approach.

ZULS / LXA LHASA / GONGGA		NAVERUS		AIRBUS		DO NOT USE FOR NAVIGATION	10-3L-2
Apply: 11881'	Doc Ref: By ATC	VERSION: 130.0	AUTHORIZATION REQUIRED		A319-115		
PALACE ONE RNAV (RNP) DEPARTURE (PALAC1) RNP 0.30 (RWY 27)		This departure requires a minimum climb gradient of 2.7% per NM to FL236. For a climb rate of 275' per NM. Altitude: 200 290 300 350 390 DME: 0.0 1.0 2.0 3.0 4.0 5.0					
TAKE-OFF: Departure not authorized above 27 degrees C. Use CONF2 only. RWY 27: Climb to FL236 via the RNAV (RNP) track to LS833. Maintain CONF 2 at or below 170 MSL until LS808. Remain at or below FL196 and do not exceed 210 MSL until LS815. Thence: Continue via the RNAV (RNP) track to TAPLIN.		Visibility of 800 meters or greater required. 27.700' (8420m) MSA RWY		RNAV (RNP) ENGINE FAILURE RNP 0.30 RWY 09 For engine failure prior to LS440 or if unable to climb LS440 or above FL236: 1. Continue via the PALAC1 departure until crossing LS823. Pull HDG and maintain RNP track. Activate ECPALC in SECOPFLN. 2. (IF) LS830. 3. Radio EN 262 verify NAV green. Continue to climb via the RWY 27 RNAV (RNP) ENGINE FAIL TRACK (See chart 10-3L-2).			

**Departure from Lhasa, Tibet,
Altitude 9,670ft,
Surrounding terrain up to 20,000ft,
Minimum Safe Altitude 27,700ft.
Considered World's Most
Challenging airfield.**



To accommodate the maximum amount of traffic into an efficiently sequenced and merged stream to the runway determined by an Arrival MANager (AMAN), it is essential that all the actors/stake holders can communicate and interact together which requires a System Wide Information Management (SWIM).

Figure 36 shows the communication between aircraft and ground stations via ADS-B, transferring navigation information from the aircraft FMS and receiving information from other aircraft and ATC which could be backed up by voice and datalink commands to separate or sequence the traffic, or information to allow the aircraft to separate themselves and share the workload with the controller.

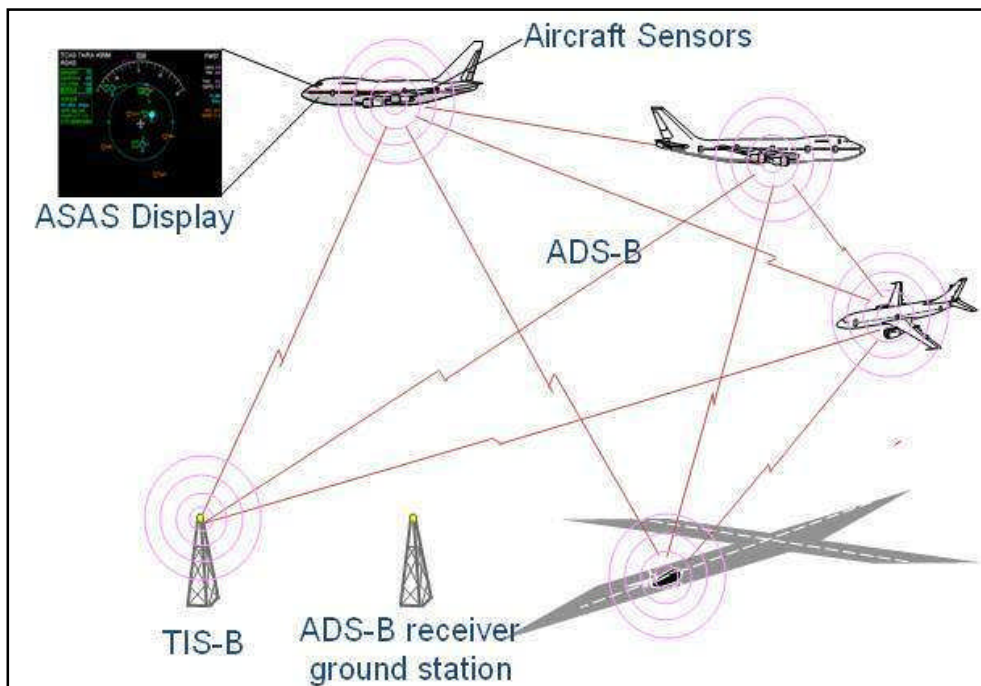


Figure 36 – Aircraft pass information from their FMS to other Aircraft and Ground stations via Automatic Dependent Surveillance-Broadcast (ADS-B), and Ground Stations return information & commands via Traffic Information Service – Broadcast (TIS-B), including to aircraft ASAS displays (Airborne Separation Assistance Systems) for crews to be able to share the separation work load with the controller on the ground.

To make a future Air Traffic Management system work a comprehensive communication system is essential to connect all the “actors” / stakeholders in the system such as the System Wide Information Management (SWIM) shown in Figure 37.

The system is similar to a networked office with aircraft as nodes/users on the network.

The system continuously accepts and exchanges information which is processed and commands and/or information is transmitted back to aircraft and other participants in the system.

Aircraft are therefore provided with information about other aircraft which can be displayed on their Navigation Displays. Aircraft crews are able to share the workload with the ground controllers by keeping separation from other aircraft using ASAS (Airborne Separation Assistance Systems) in cruise or during descent and approach by following aircraft in an orderly stream to the runway.

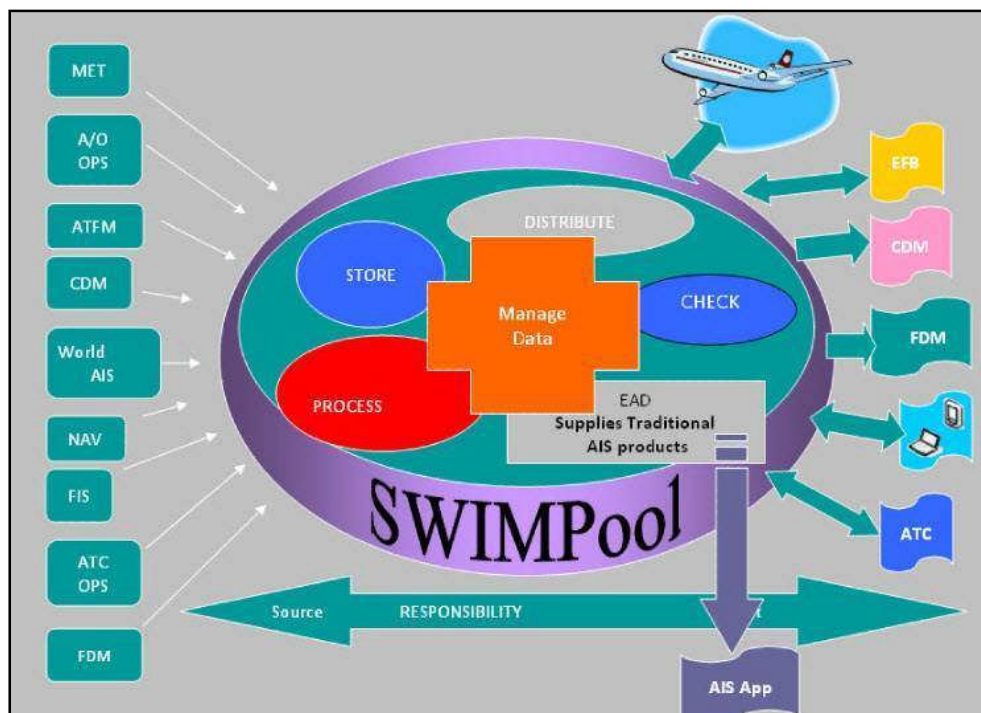


Figure 37 – System Wide Information Management (SWIM) is an essential part of a future ATM system and is similar to a networked office with aircraft as nodes/users on the network. The system continuously accepts and exchanges information which is processed and commands and/or information transmitted back to aircraft and other participants in the system.

A future plan aimed to be in service by 2020 for traffic to be controlled by 4D Trajectory Management is shown in Figure 38. An aircraft's Reference Business Trajectory can be developed from the airlines' schedule, modified according to other traffic and finally authorised by the Air Navigation Service Provider, to be executed by the crew to comply with the Controlled Time of Arrival at the destination.

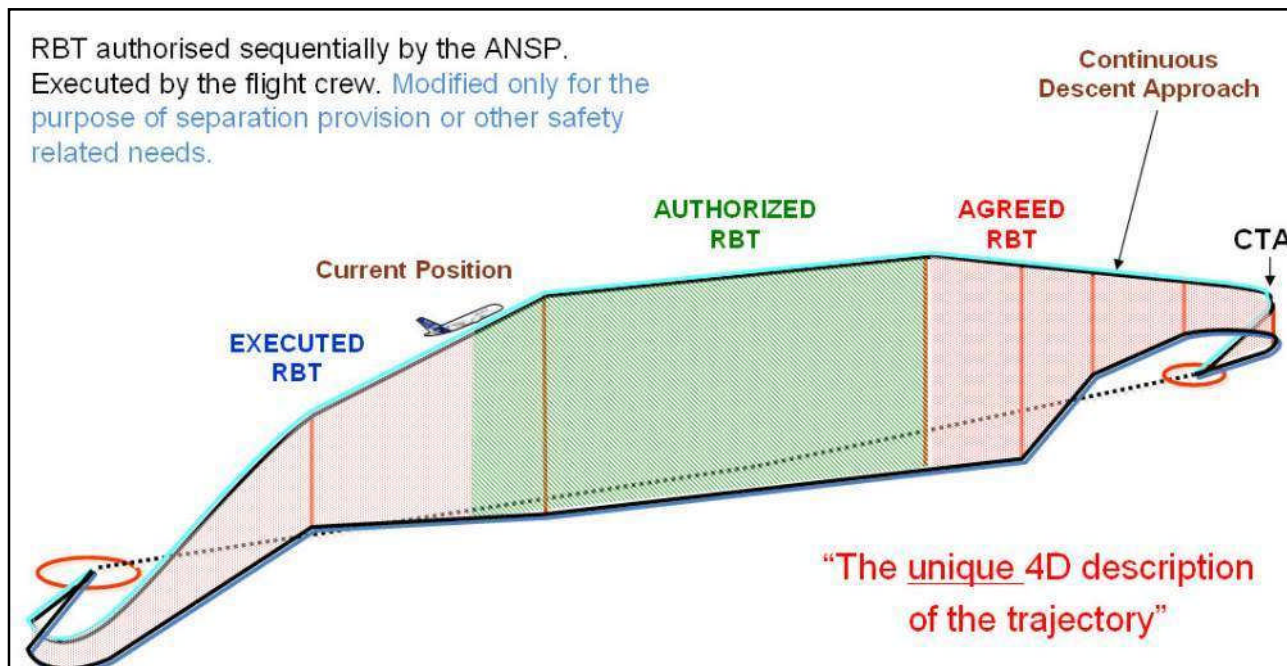


Figure 38 – Air Traffic Control by Trajectory Management - An aircraft is assigned an Reference Business Trajectory (RBT) by the Air Navigation Service Provider (ANSP) which commits the aircraft to fly the trajectory and arrive at the destination at the Controlled Time of Arrival.

Such future systems depend upon new equipment coming on stream both on the ground in the air. Figure 39 shows the progress of Airbus' future Air Traffic Management equipment that is being developed and fitted.

<p>Step 1. ADS-B Out A/C information broadcasted for ground use in a first step</p>		<p>A380 : Cert in 2007 A320/A330/A340 : Cert Q1 2008</p>
<p>Step 2. ATSAW Display of other aircraft ADS-B Info in the cockpit</p>		<p>Development launched Test A/C flying since 2007 Cert Target date : 2009</p>
<p>Step 3. ASAS SPACING A/C instructed to maintain Spacing with target aircraft</p>		<p>Part of mid-term baseline of SESAR Airbus target : 2013</p>
<p>Step 4. ASAS SEPARATION A/C instructed to maintain Separation with other aircraft</p>		<p>To be refined Airbus in line with SESAR target</p>

Figure 39 – Airbus Progress with Development of Aircraft Equipment in Future ATM Systems

13. "FUTURE" AIR TRAFFIC MANAGEMENT FUEL SAVINGS BEING ACHIEVED NOW - USA

UPS are already using their own ABESS (Airline Based En-Route Sequencing and Spacing) system to enable their crews to fly efficient CDAs into Louisville, Kentucky, USA, which UPS operations have developed in agreement with the FAA and which is shown in Figures 40a to 40d.



Figure 40a – Satellite image showing the Merging and Spacing Zone in cruise when UPS use their ABESS (Airline Based En-Route Sequencing and Spacing) system to organise their aircraft into an orderly stream prior to descent, when the crews then maintain their spacing from the aircraft they have been told to remain behind using the information on their modified Navigation Displays as in Figure 33b.

Figure 40b UPS Operations Control uses ABESS to Sequence & Merge aircraft during Cruise

Communication systems & Displays in UPS aircraft then allow crews to manage their own FDMS (Flight Deck Merging & Spacing) during an idle thrust descent.

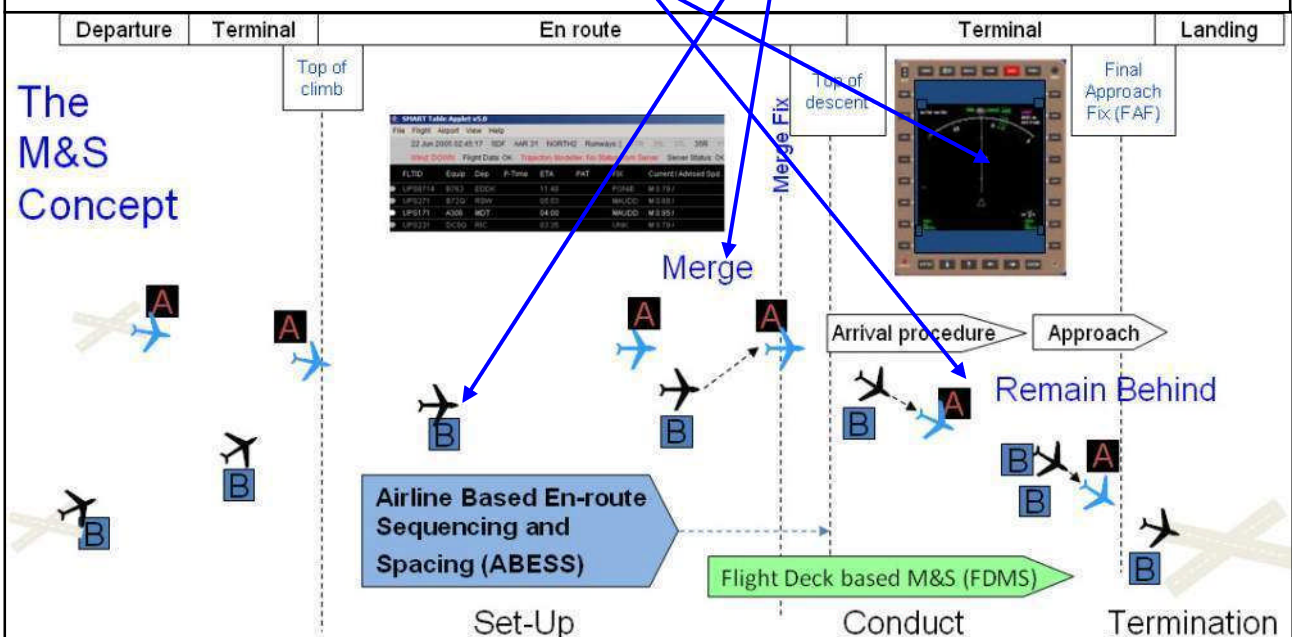




Figure 40c – Type of Navigation Display Showing Information of Other Aircraft
 Similar to the ND used by UPS crews to maintain spacing behind the lead aircraft during descent and approach, thus making fuel efficient and quiet Continuous Descent Approaches from Cruise Altitude.

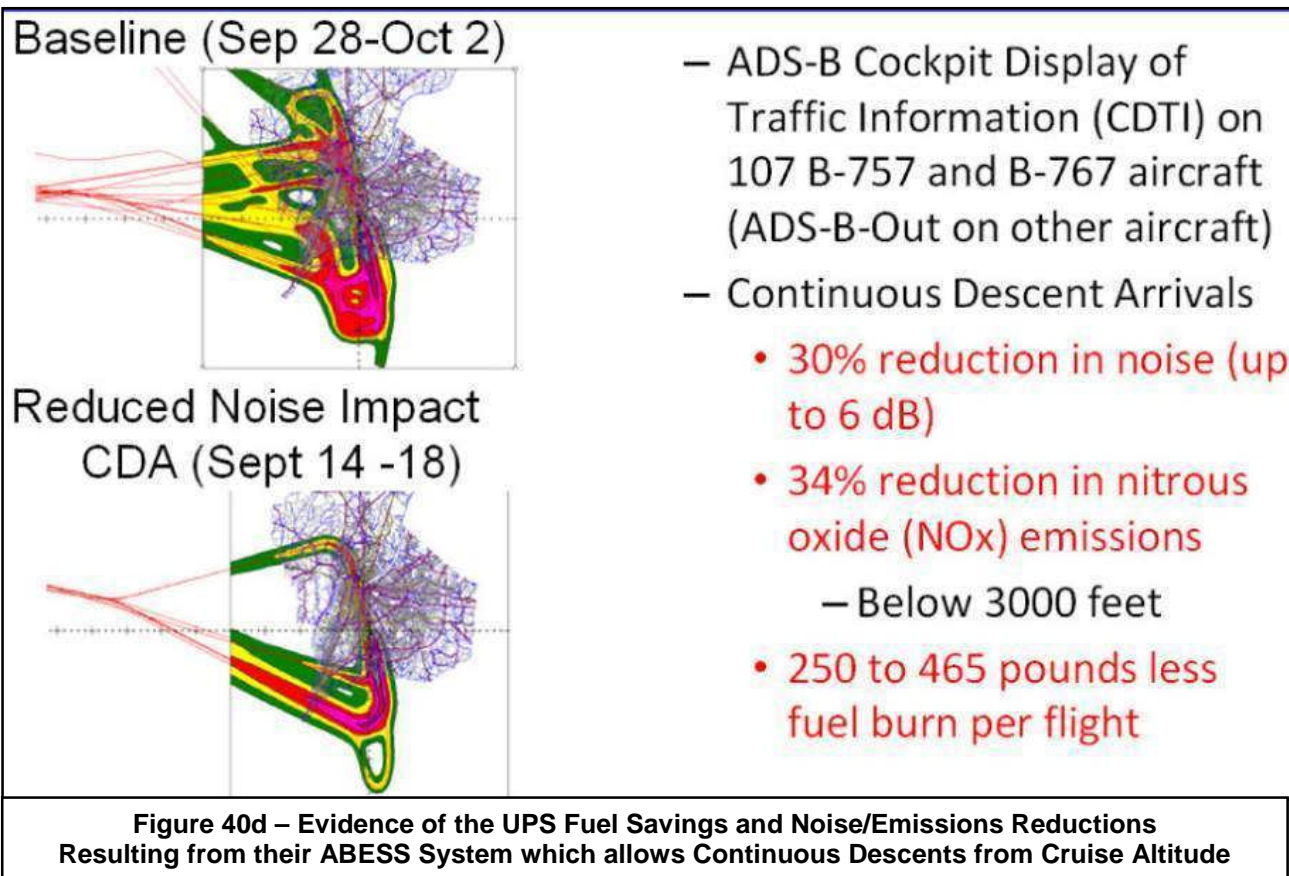
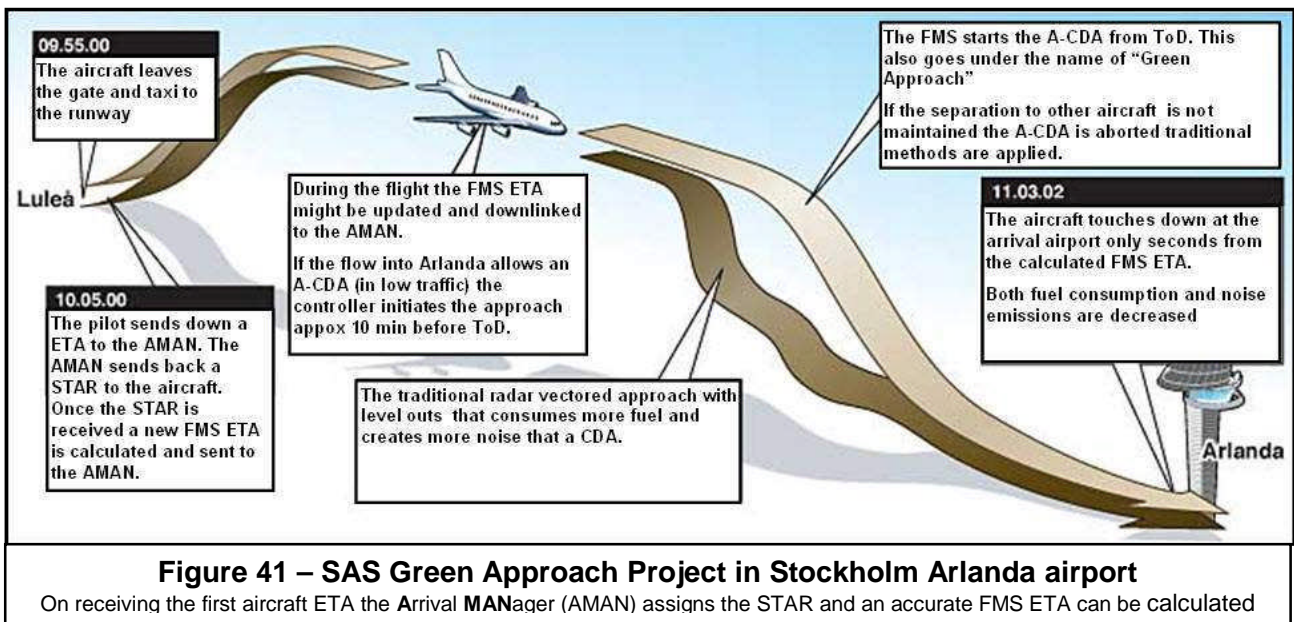


Figure 40d – Evidence of the UPS Fuel Savings and Noise/Emissions Reductions Resulting from their ABESS System which allows Continuous Descents from Cruise Altitude

14. "FUTURE" AIR TRAFFIC MANAGEMENT FUEL SAVINGS BEING ACHIEVED NOW - Europe

As mentioned on Page 8 under Cruise Savings the Swedish led EUMetNet-AMDAR has been cooperating with the Green Approach project into Stockholm Arlanda airport which is shown in Figure 41.



The Swedish aviation authority LfV (Luftfartsverket) has overall responsibility for the NU2 Plus project, based on research from the North European ADS-B Network or NEAN started in 1995, and now aims to validate a set of applications, based on ADS-B and 4D Trajectory data, in live trials to reach operational introduction. Besides SAS, partners include Eurocontrol, Boeing, Thales, Airbus and AVTECH Sweden AB which is developing much of the software and is responsible for its implementation.

AVTECH uses its AASES (Airborne Air Traffic Management System Engineering Simulator) to validate the new applications, being the world's first platform capable of sending 4D Trajectory data over internet for real time simulations.

The 737-600 NG in the trial has an "intent bus" which can be used to data link the airplanes flight path to the ground and used to set up the inbound flow of aircraft.

The AVTECH software on the ground uses the current wind data from aircraft ahead to pick the best winds to uplink to the aircraft based on its descent path, as shown by the AVTECH NowForecast in Figure 42.

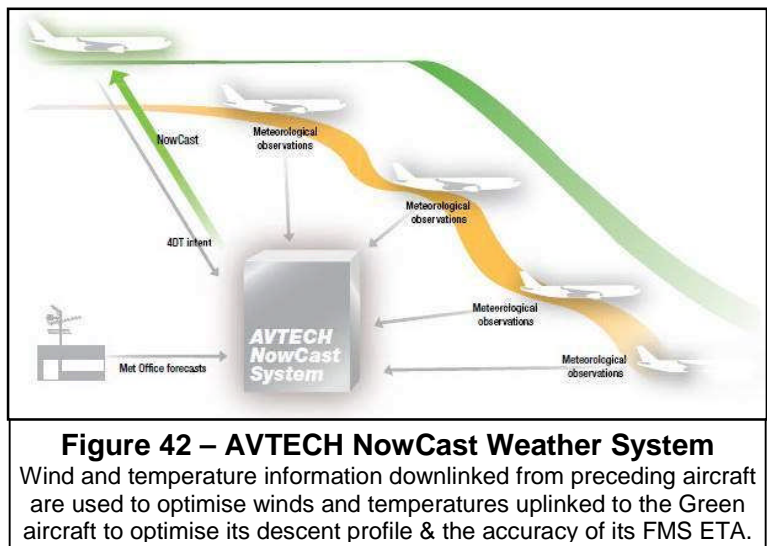
Using this system the landing time can be within seconds of the FMS ETA compared to minutes in a normal operation

The order of aircraft determined by AMAN (Arrival MANager) will involve CDM (Collaborative Decision Making) by the Airline, ANSP (Air Navigation Service Provider) and the Airport.

The expectations within the project, which will be validated in simulation, is to use the downlinked trajectory information in the ground system in order to finally enable Green Approaches during more dense traffic periods.

If Air Traffic Controllers are given aircraft ETAs based accurate 4D navigation when aircraft are an hour from the airport, controllers can use the aircraft's ability to slow down or speed up by as much as 6 min to provide an orderly and smooth arrival.

A similar project has been operating with a Novair Airbus A321 aircraft and using RNP procedures designed by the Swedish LfV to minimize track miles – up to 14 nautical miles – and circumnavigate noise sensitive areas. It is the first RNP procedure that has been developed for this purpose in Europe being sponsored by the Atlantic Interoperability Initiative to Reduce Emissions (AIRE).



15. ACCIDENTS WHICH NEED NOT HAVE HAPPENED – Quiet Fuel Efficient Approaches are also Safe!


The new RNP Approaches generally require an accuracy of 0.1 nautical

DME (Distance Measuring Equipment) reads to 0.1 n mile, therefore:
 Altitudes on a 3 degree glidepath can be checked / flown to within 30ft (300 x .1)
 (It is important to use the correct DME - ILS or VOR if both are available!)




A DME in line with a runway can show an accurate glidepath on a Non Precision Approach by a simple DME-Altitude table for a Constant Descent Angle approach.
 Step Down NPAs and many accidents could have been avoided 30 years ago.
 Examples are shown in Figures 43 - 46

- **TWA B727 Accident into Washington Dulles in 1974**
 - Hit hill at 1,700ft at 25 nm when should have crossed 1,800ft at 4.8 nm
 - FAA mandated all US carriers to fit GPWS
 - No comment about better use of DME during descent and approach?
 - *If the FAA had also mandated that DME approaches must be Constant Angle – Many lives would have been saved in the following 30 years*



AIAA, 21st Sept 2004 – Hugh Dibley: Impact on Safety of Incorrect Baro Altitude Temperature Errors Including Non Precision Approaches 4



KAL B747 Crashed on LOC (G/S out) into Guam 6th August 1997



LOC GS Out Approach but DME on VOR 3.3 nm short of r/w

Step down / "Dive & Drive" Approach

No clear DME-Altitude Tables for VNAV checks

Glideslope flag was occasionally cleared by local FM radio station

Crash site on hill 660 ft was above MDA of 560 ft for LOC (GS out) approach

Suggestion for Constant Angle LOC (G/S out) Approach to Guam 06

Constant angle 3.3° glidepath defined by DME-Altitude table which can easily be flown using V/S or FPA

(The profile is similar to Toulouse VOR DME 14/R used by students in training without difficulty)

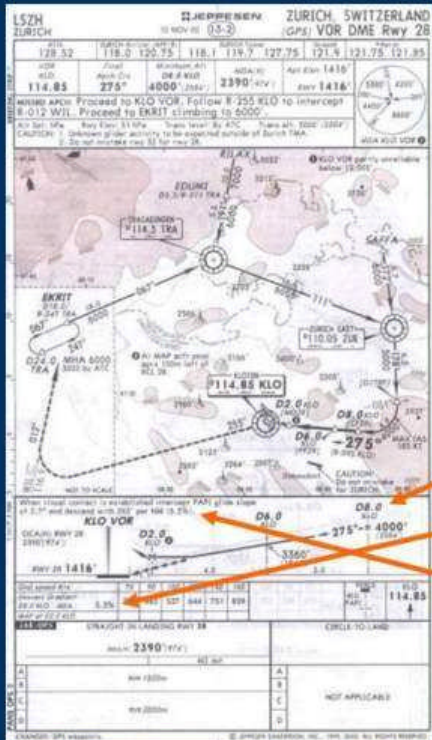


NTSB report recommendation No 9 erroneously suggests tables showing Altitude – Distance to Runway. ** Altitude – Distance to DME ** is essential for instant cross-checks

Figure 44 - Second Example of an accident which need not have happened
 If a the approach had been drawn as a CDA using a DME-Altitude table as shown

RJ100 Non Precision Approach Accident into Zurich November 2001

VOR DME Rwy 28 Chart in use



No DME-Altitude Table.
Crew could not cross-check profile continuously during approach.
PNF unable to monitor properly.

(Aircraft descended below profile and hit hill. Captain remarked having visual contact.)

Dual Segment NPA

- Start Approach at 8 DME - 4,000 ft
- on 5.3% gradient [3.0° not shown] to 6 DME - 3,360 ft
- Continue on 5.3% gradient, 'When in Visual contact with 3.7° PAPIs Descend with 394 ft/nm (6.5%)'



AIAA, 21st Sept 2004 – Hugh Dibley: Impact on Safety of Incorrect Baro Altitude Temperature Errors Including Non Precision Approaches 14



RJ100 Non Precision Approach Accident into Zurich November 2001

Chart with DME-Altitude Table to constant 3.7° angle glidepath



Constant Angle NPAs are now recommended by ICAO. Should not also standardised DME-Altitude tables required to be shown on all charts?

Airbus FMGC Database contains ZRH 28 VOR DME Approach with 3.7° Profile, which can be flown 'managed', automatically to MDA.

The same 3.7° approach can easily be flown 'selected', using a DME – Altitude Table. Providing a simple monitoring task, even for inexperienced crew members.



AIAA, 21st Sept 2004 – Hugh Dibley: Impact on Safety of Incorrect Baro Altitude Temperature Errors Including Non Precision Approaches 15



Figure 45 - Third Example of an accident which need not have happened

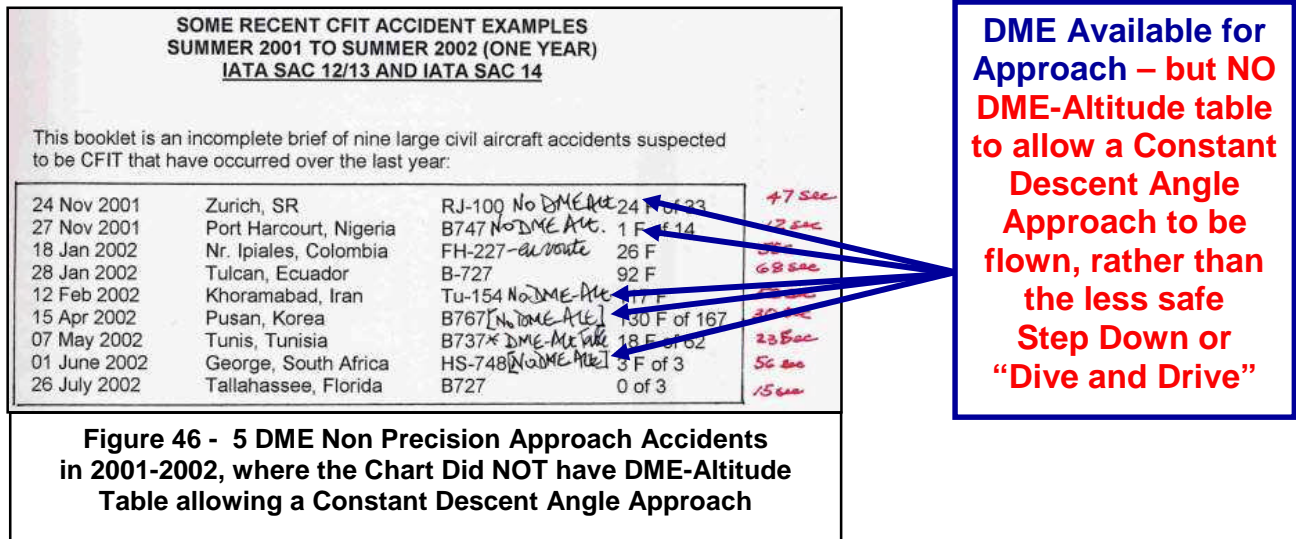
The approach as drawn had no effective vertical checks, but could be flown as a CDA using the DME-Altitude table.

14. ACCIDENTS WHICH NEED NOT HAVE HAPPENED – continued

Don Bateman of Honeywell, the father of EGPWS which shows terrain on the aircraft navigation display and gives an earlier warning than GPWS, so has further reduced the accident rate, highlighted that 9 accidents in 2001-2002 could have been saved if EGPWS had been fitted to the aircraft, shown in Figure 46.

However 5 of the approaches had a suitable DME available.....

but **the charts had NO DME-Altitude table** for the crew to easily fly a Constant Descent Approach.



There is absolutely no doubt that GPWS (Ground Proximity Warning System) followed by Enhanced GPWS have greatly increased aircraft safety.

The FAA required GPWS to be fitted to all US registered aircraft as a result of the TWA 727 VOR DME Step Down/"Dive and Drive" accident into Washington Dulles runway 12 in December 1974, shown in Figure 43, when the aircraft flew into a hill at 1,670ft when 25 miles from the airfield.

However GPWS is a long stop/goal keeper tackling the outcome of the crew error but not the basic cause.

There were several factors in the TWA accident which was flown by the First Officer while the captain read the approach chart, but if the crew had kept the aircraft close to the optimum descent profile shown by the airfield DME, followed by a Constant Descent Angle VOR DME approach, this would have kept the aircraft safely well above the ground as well as flying an approach which would have saved fuel and made less noise over the ground.

If the FAA had also stipulated that proper use be made of an airfield DME to fly a safe, efficient profile, and that wherever possible all DME based Non Precision Approaches should be constructed using as Constant Descent Angle defined by a DME-Altitude table in preference to the Step Down profile, many non precision approach accidents over the next 30 years might have been avoided.

Most European operators adopted Constant Angle Non Precision Approaches using simple DME-Altitude Tables with zero cost, but the FAA continued to advocate Step Down Approaches – and waited for 30 years for such "Dive and Drive" approaches to be eliminated by RNP AR equipment which has to be fitted to all aircraft.

This policy also affected operations worldwide which were under US influence, and in the following years Non Precision Step Down Approaches formed a major part of CFIT accidents which became the highest accident cause. Accidents included the Flying Tigers B747F into Kuala Lumpur in February 1989 and the Korean B747 into Guam in August 1997 shown in Figure 44.

At the time of the TWA accident I was regularly operating B747s for BOAC/BA route Detroit-Washington-London when the most efficient arrival into Dulles airport was a VOR-DME to runway 12, using the circular Glidepath computer shown in Figure 29, to fly a Constant Descent Angle Approach as the DME-Altitude tables had not yet been printed on the Aerad approach charts. I found it sad and difficult to understand that the TWA 727 was at 1,670ft when at 25 miles DME while we would be close to 7,000ft, and that the FAA did not subsequently emphasise better use be made of DMEs as well as mandating GPWS.

The message remains that Distance-Altitude Tables should be shown on all approach charts so that the profile can be check at anytime during the approach – not just at mandatory points which can missed due to workload such as radio calls, etc. This applies to RNP approach charts as well as for approaches still defined by DMEs.

It is unfortunate that the Flight Safety Foundation CFIT Task Force in the 1990s did not emphasise the benefits of DME-Altitude tables to fly accurate Constant Descent Angle Non Precision Approaches which could have encouraged their use throughout the industry, and perhaps have saved accidents such as these.

15. CONCLUSION

I hope this presentation has given an insight into operational savings which can be made by the Flight Crew.

On early less automated aircraft crews could make substantial savings if they made best use of the information that was available to operate as efficiently as was possible at the time, but on the other hand considerable waste and disturbance to the environment could occur by operating away from the norm.

In due course the future sophisticated aircraft and ATM systems should be capable of keeping the aircraft operation close to optimum, and with flight crews and ground controllers working together this should enhance their understanding of each others' roles and bring further benefits to the industry, and be able to reduce fuel burn/emissions and noise to meet the targets which have been set for the future.

In turn the industry must make sure that operators and their crews have the information and training to make they are able to extract the maximum benefit from the new technologies and avoid some of the pitfalls which have occurred in the past.

This paper has shown that Constant Angle Approaches could be flown efficiently by a DME in line with runway and a simple DME-Altitude table or slide rule to check the descent profile – and it was not necessary to wait for GPS RNP systems to avoid the Step Down Non Precision Approaches which have caused the loss of so many lives over recent years. It is vital that Distance-Altitude tables are still provided to enable the descent profile to be checked throughout an RNP approach but using RNP distance information to the runway rather than the previous DME distance.

There may be other similar examples in future as new equipment becomes available.

However many of the features of the systems can be used NOW – just as UPS have implemented their in ABESS and FDMS to fly efficient CDAs into Louisville.

Why cannot the UK make better use of the FMS 4D capability to give aircraft arriving from the West a Required Arrival Time to reduce wasteful holding?

Why do not airlines campaign to use this facility? It is extraordinary to have an aircraft fly for 13 hours from Hong Kong and then hold because it is too early to land before a time which had been published by the airport years in advance!

Hugh Dibley's CEAS Paper 27 October 2009 - Appendix A

Part of the History of Continuous Descent Approaches into London Heathrow Airport Starting in 1975

Pages 2-7 Article March 1974 Journal of the Guild of Air Pilots and Air Navigators

How to Reduce Noise and Save Fuel - Now by Hugh Dibley

proposing that:

1. ATC give aircraft expected DME distances and Flight Levels for bottom of descent points, so that crews could plan idle thrust descents from cruise altitude efficiently to the holding / inbound approach fixes, given suitable forms of guidance,
2. After leaving the holding fix, that the vectoring speed be increased above the then standard speed of 170 kts IAS to at least 200 kts IAS, to enable aircraft to be flown clean / without flaps for as long as possible,
3. Ideally from the holding fix, the track miles should allow a descending approach on about a 3° / 300 ft per mile gradient to smoothly intercept the ILS glideslope with minimum thrust and any need for thrust changes,
4. The height for intercepting the ILS glideslope to be increased from the then 2,500 ft to as high as practicable,
5. In suitable weather conditions, aircraft should be kept "clean" for as long as possible, lowering the gear at about 1,500 ft above the airport to be stabilised by 1,000 ft,
6. DMEs should be installed to show the distance from the runway to allow crews to judge their descending approaches efficiently.

(NB: At the time ILS DMEs were not provided as part of the ground navigational system and some airlines indicated their unwillingness to pay for the installation, therefore the UK Department of the Environment funded the cost of the ILS DMEs at LHR for noise abatement, which were installed in 1978.)

Page 8 Copy of letter from UK NATS dated 7th May 1974 in response to the GAPAN Article of March 1974, which led to work on Continuous Descending Approaches.

Page 9 Flight International 25th September 1975 describing Lufthansa Managed Drag Approach procedures which were similar to the proposals in the GAPAN article of March 1974, and the resistance by the UK CAA to the DLH procedures but emphasizing that these were being supported by BA Overseas Division.

Page 10 Economist 20th September 1975

Page 11 Guardian 21st September 1975

The newspaper articles mention the UK CAA and British Airways European Division's resistance to DLH's Managed Drag procedures which could reduce noise in central London.

Both illustrations used show similarity to that in the earlier GAPAN article on Page 6.

Page 12 Example of Dibley Descent Computer showing how to follow an efficient idle thrust descent profile from cruise altitude for an ATC clearance which defined an altitude and DME distance at the bottom of descent.

JOURNAL OF THE GUILD OF AIR PILOTS AND AIR NAVIGATORS

March 1974

How to Reduce Noise and Save Fuel - Now

By Senior First Officer Hugh Dibley *

(Liveryman and Vice-Chairman, Technical Committee, who is expressing a purely personal view)

FUEL conservation has always been a major factor in efficient airline operations but it is being highlighted by the present crisis (1974). During climb and cruise it is relatively simple for a pilot to extract the best performance from the aircraft, mainly by flying at the correct speeds and at the optimum altitude for the aircraft weight. But during descent and approach practical information may not be so readily available which can lead to a considerable drop away from optimum efficiency.

Poor descent and/or approach operation dramatically increases the amount of fuel burnt – at least 20 per cent on a short sector – besides making life under the approach path unnecessarily noisy.

Air Traffic Control obviously largely governs an aircraft's navigation in a complex terminal area such as London. It is important that the profile prescribed by ATC should be as close to the aircraft's optimum descent and approach path as possible.

(An ideal profile for minimum fuel burn - but not minimum noise - is shown in Figure 1)

The aircraft descends from the cruise altitude at point A with minimum power to Point B at circuit height, and then decelerates to approach speed before starting its final approach at point C to land at D.

A good approach is a prerequisite for a safe landing, so it is vital that the aircraft is properly stabilised at the correct speed in the landing configuration (gear down, landing flap) in the last 1,000 ft or 3 miles of the approach to land.

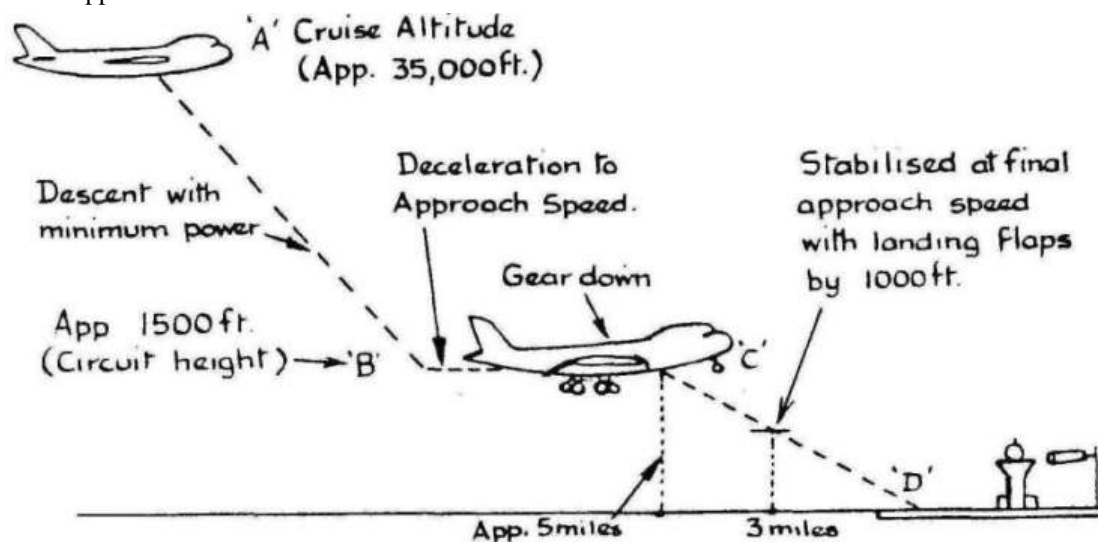


Figure 1. Ideal Descent & Approach to Land for Minimum Fuel (for noise see Fig. 6)

The final approach angle C-D (approximately 3° or 300 feet per nautical mile) is common for all current jet aircraft. The Top of Descent Point A must be determined accurately so that the aircraft decelerates smoothly from B to C, with flaps and landing gear being extended as power is applied to establish the aircraft on the final approach. (Flaps are ideally selected at about 10 miles and the gear about 5 miles to touchdown).

The descent profile A-B varies not only between different aircraft types but with individual aircraft's descent speed and landing weight as shown in Figure 2.

* The author is a 747 pilot instructor with British Airways and an IRE and TRE on the 747 Simulator

This shows that a heavy Boeing 747 descending slowly at about 260 kts for best fuel economy follows a gradient of about 280 ft per mile, starting down from 35,000 ft about 135 miles from the runway; at the other extreme a 747 descending at maximum speed (Mach .89/390 kts IAS) would need less than 50 miles. For a descent at 340 kts IAS the descent distance for a heavy 747 is 95 miles against 65 for a light aircraft – the gradient being 380 and 550 ft per n mile respectively.

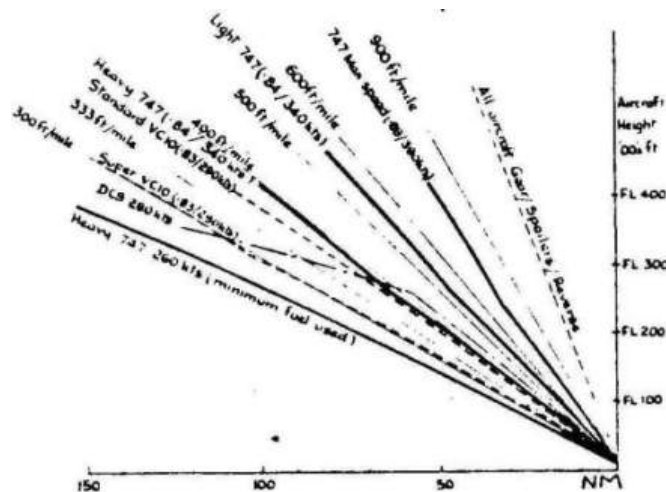


Figure 2. Examples of Aircraft Descent Profiles

Due to its lighter weight and greater drag a standard VC10 needs 25 miles less than a Super VC10 at the same speed, while some aircraft, e.g. the DC9 and BAC111, which require engine power for pressurization at high level, descend slowly to about 25,000 ft, and then at about 400 ft per mile at 250 kts IAS.

Most pilots rely on mental arithmetic based on rules of thumb to compute their descent profile – 300 ft per mile is popular as the sums are easy (Height = Distance X 3) and it suits the bigger jets (707, 747, Super VC10 etc) well at about 280 IAS.

But as Fig. 2 shows, the situation can get beyond a mental solution, and even when it is relatively simple many pilots will descend early to be safe. The effects of getting the profile wrong are considerable, as illustrated by Figure 3.







Height	Mach/IAS	Configuration	Fuel Used for 8 miles	Time for 8 miles
37,000ft	.84/275	Clean 	150 kgs (40 galls)	1 min
10,000ft	340kts	Clean 	265 kgs (70 galls)	1.25mins
5,000ft	240kts	Clean 	310 kgs (85 galls)	1.9mins
5,000ft	200kts	1 st Flap 	350 kgs (95 galls)	2.2mins
5,000ft	170kts	10 th Flap 	470 kgs (130 galls)	2.6mins
5,000ft	150kts	Gear down 20 th Flap 	770 kgs (210 galls)	2.9mins

Figure 3. Increased fuel consumption by low altitude and low speed operation with flaps and gear

Descending / 1 minute (8 miles) early on a 747 and extending flaps and gear on reaching circuit altitude uses an extra 620 kgs (170 gallons) of fuel and adds 2 minutes, to the sector time.

A 747 descent computed at 300 ft per mile but flown at 340 kts IAS could end up 55 miles short of the field. If approach flap was then selected, with the gear still up, over 2,000 kgs (550-600 gals.) extra fuel would have been burnt, and 11 minutes added to the flight time.

Varying descent techniques between individual pilots, companies and aircraft can be one of the largest problems for ATC especially if an aircraft's ground-speed is not displayed on the ground radar.

When entering a complex terminal area under most present ATC systems, aircraft can be given an altitude at which to cross a particular point during descent and it is important from all aspects that pilots comply with the clearance efficiently. Fig. 4 shows the effect of failing to do so.

Not only does aircraft B waste 200 gallons of fuel and 6 minutes of aircraft time but the job of the controllers is made that much more difficult. The aircraft could be anywhere in 24,000 ft of sky if they wished to coordinate crossing traffic over Lyneham. Longitudinal separation might be eroded extremely quickly and this has led to misidentification of radar returns where one aircraft has unexpectedly overtaken another. (Think if B had been a Standard VC10 descending at 290 kts and A a 747 at 390 kts)

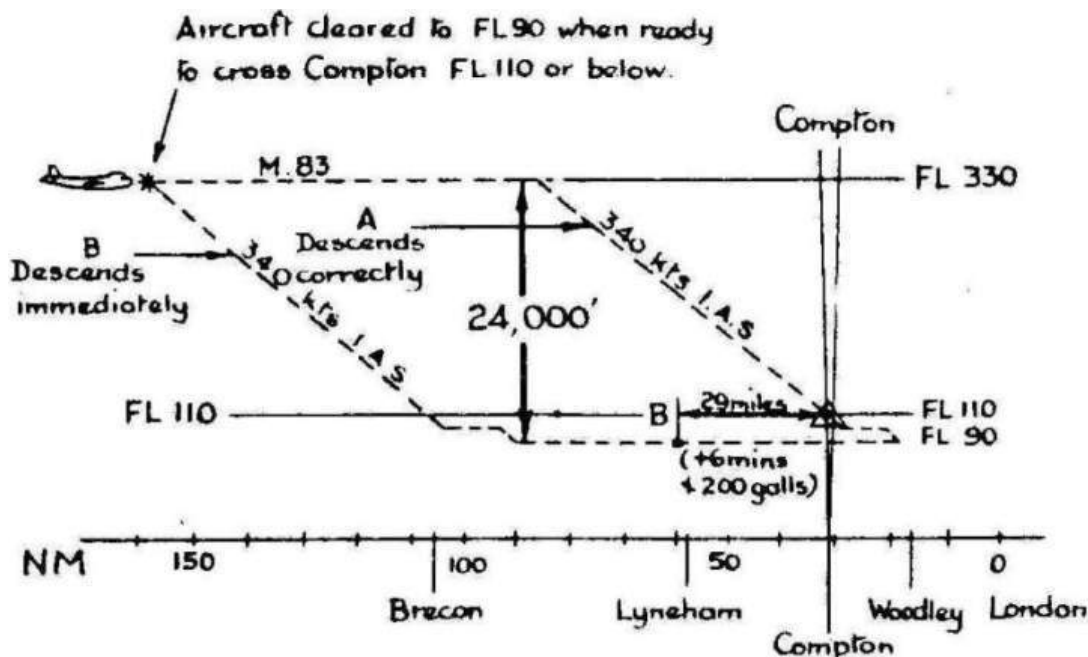


Figure 4. A 747 is cleared to FL90 to cross Compton FL110 or below. Pilot A descending at the correct point, crosses Compton 29 miles / 6 mins, ahead of Pilot B, who descends immediately, burning 200-250 gals. more.

Some controllers are therefore tempted to try to navigate the aircraft vertically themselves by giving positive instructions when to descend. Again *Figure 2* shows that they have little chance of doing this efficiently—unless practically knowing the pilot's name and aircraft weight, let alone the type etc! Further confusion might be caused as some airlines recently have reduced cruising speeds to save fuel. On starting descent the aircraft can “dive” off some thousands of feet to achieve its normal descent speed, possibly thereby losing all the savings gained by cruising slower!

The time has surely come for all pilots to have some form of descent guidance to allow them to plan their descents accurately, and monitor the correct profile throughout descent. This should be possible for all types of aircraft, not only those whose aerodynamics happen to suit the mental arithmetic of the pilot.

The latest types of Area Navigation Systems are capable of limited vertical navigation. But they are expensive, and not only are operators reluctant to retrofit present aircraft but some airlines do not even consider it worthwhile to fit to the latest aircraft (e.g. DC10, TriStar). The problem is that the full benefit will not be available from ATC until most aircraft are able to navigate vertically with a certain degree of accuracy, which appears to be many years away at present. (*The Concorde will probably enter service without vertical guidance.*)

Figure 5 shows a simple circular slide rule (kindly made by Airtour flight Equipment Ltd) which can enable all aircraft to follow a vertical profile accurately *now*. This version shows a standard 747 descent (340 kts IAS to 10,000 ft with 250 kts IAS, for a landing weight of 250,000 kgs) but models can obviously be drawn up to suit any aircraft at any particular speed and configuration — e.g. for maximum fuel economy at minimum drag speed; or for minimum time at V_{mo} (maximum operating speed) — (see *Fig 2*)

Using the computer it is quite simple to navigate to within a few hundred feet vertically (i.e. a mile horizontally) whereas pilots would be content to be within a few thousand feet if relying on their mental prowess. Indeed, an analysis of reports shows that pilots using the computer estimate their accuracy has been improved average 9 miles horizontally (4,000 ft vertically). *Figure 3* shows this is worth at least 40 gallons on a 747. i.e. the cost the computer is covered by *one* sector's operation (British Airways operates some 400,000 sectors annually).

The computer in Figure 5 is set to solve the crossing clearance in Figure 4 — cross Compton (31.5 DME London) at FL 110 or below. 31.5 on the inner distance scale is set under 11(000 ft) on the outer scale. Descent from FL 330 is started at about 87 DME; if the groundspeed is 500 kts, the rate of descent required is 3,300 ft per minute as shown on the extreme outer scale: as the groundspeed drops off with height so the rate of descent will be reduced. (Wind is allowed for by making the rate of descent proportional to *ground speed*). Continuous altitude versus distance checks are available without effort — i.e. at 69 DME—FL260. 44 DME—FL 160 etc. Continuing below FL 110, if speed was reduced to 250 kts at FL100 the aircraft would cross Woodley (16 DME) at about FL 85, or at about FL50 if 340 kts was maintained below FL 100. The whole thing could be set up on the Ockham DME just as well, or else using aircraft's INS or doppler, assuming it to be sufficiently accurate

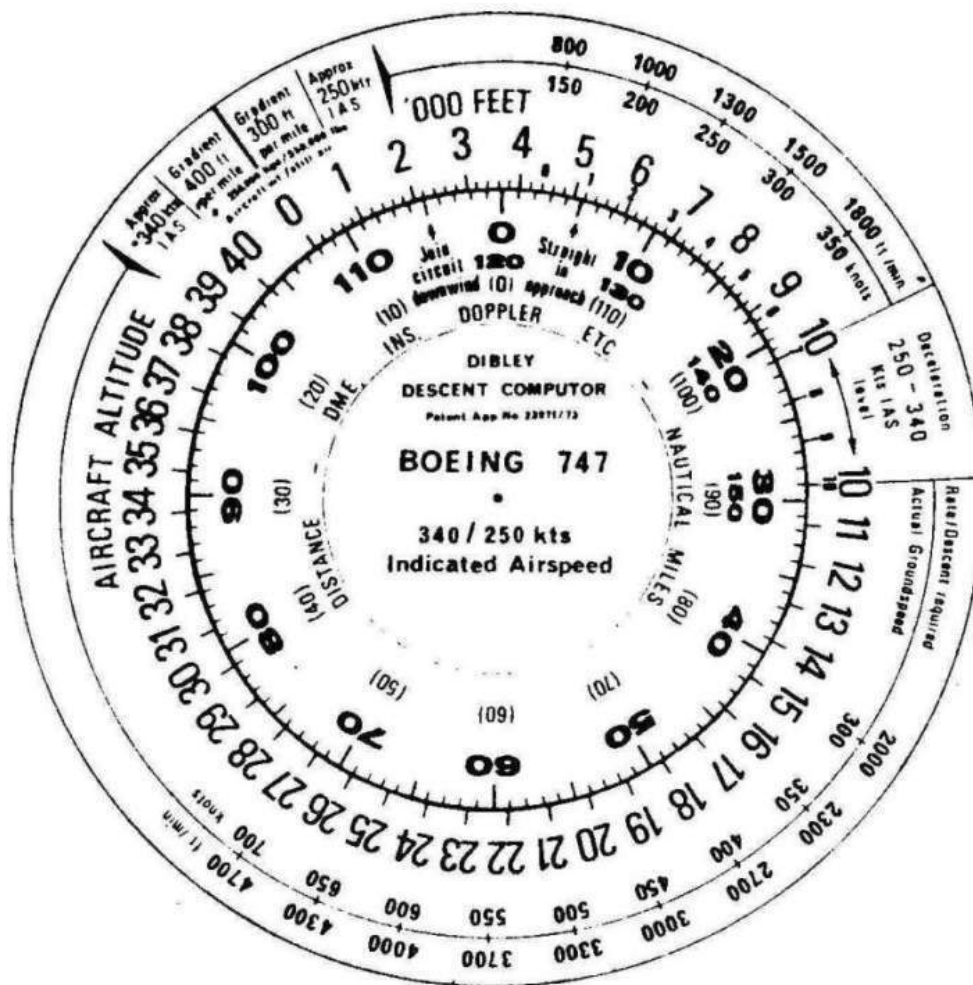


Figure 5. The Dibley Descent Computer

Although not revolutionising the Air Traffic Control scene, accurate vertical navigation on descent could help the situation a great deal. Not only could controllers rely upon pilots conforming to their vertical clearance uniformly, but by avoiding the type of gross variation shown in Figure 4. the flow of aircraft to the approach director should be organised more easily. Controllers could give an expected final crossing clearance when ever possible — this might be the lowest slack level — which would benefit operators considerably as pilots could use their aircraft's optimum cruise and descent procedure to the maximum.

Below this crossing altitude/fix, pilots must obviously expect to be vectored tactically by radar to allow

the director to establish an orderly stream for landing. *Ideally, the height and track miles to touch down should combine to give a gradient of about 3° or 300 ft per mile* but this is obviously not always possible. Speed control will almost certainly be needed at a busy airport, but it is vital that a *sensible speed* is used.

170 kts has been the universal speed for controllers at London over the past few years. It is not unusual to be vectored from Ongar/Lambourne in Essex to land on 10 Left (over Windsor Castle) or from Woodley, near Reading to the 28s (over London), i.e. about 60 miles at 170 kts. Table 2 shows that on a 747 this can use an extra 200 gallons per approach over a higher speed allowing the aircraft to be kept clean. (*In the USA, the ATC rules state that a speed less than 200 kts will not be used for normal vectoring to an IFR approach*).

A speed of 170 kts has often been called for with hardly another aircraft airborne in the UK — e.g. a freighter arriving at 3 am — causing undue noise pollution. (*Concorde burns 25,000 kgs an hour at 170 kts — more than when cruising at Mach 2 i.e. 1,100 kts.*)

Not only should the vectoring speed be increased but pilots should be given the option of flying their own approach when traffic permits.

An area where pilots themselves can make considerable savings, not only in fuel but in noise, is in the final approach path. The approach director normally turns aircraft onto the runway centre line at about 10 miles from touchdown — on a busy day it can be 20-30 miles — and a height of 2,500 to 3,000 ft. *Figure 1* shows that for a safe approach the gear and landing flap must be selected at about 1,500 ft or 5 miles: assuming the weather is fine there is no need to do so much earlier. Yet regularly on a beautiful day, without a cloud in the sky, people on the ground get blasted to pieces by aircraft thundering over the middle of London with everything hanging out.

Some aircraft require the gear to be extended early for an autoland, but surely such autolands need only be made on a small proportion of approaches in good weather.

The 747 isn't a particular noisy aircraft but on the other hand from *Figure 2* it can be seen that if gear and approach flap are extended 8 miles early, rather than flying at 180 kts with 5° flap, an extra 100 gallons is burnt.

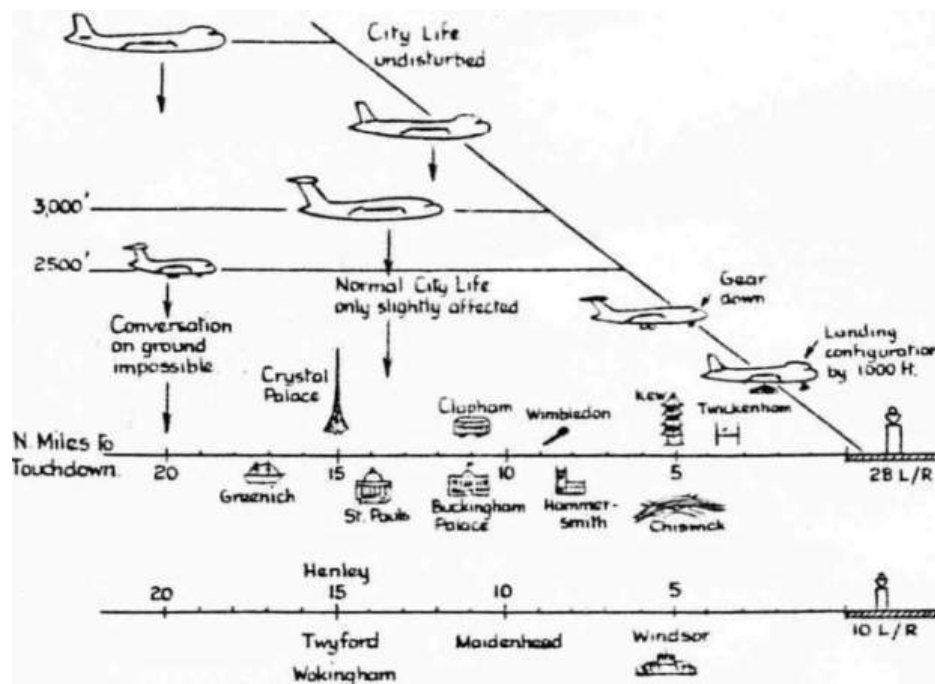


Figure 6. The effect on the environment of aircraft approaching at various levels, with and without gear and / or flaps extended.

Figure 6 shows the approach path over London and the effects on domestic life of premature dirtying up of aircraft. Even 10 years ago, you could always tell a TWA 707 because it was inevitably flying cleaner and quieter than most other aircraft. Now other operators seem to be getting the message! It is interesting to see various airlines' performance on the approach. I think that someone isn't really trying if the gear is down much before the Chiswick Flyover.

(There is much talk about the steep noise abatement approaches that are happening in the USA. Before we think about those, let's make our present procedures as quiet as possible — without impinging upon safety or re-equipment and re-training. Perhaps ATC could be persuaded to raise the height for flying over London — 2,500 feet over Regents Park is quite absurd?)

With a DME tied in with the ILS there is no excuse for getting settled down unduly early.

To Summarise

1. Airlines should be encouraged if not actually required to adopt some form of vertical navigation aid as soon as possible.
2. ATC should give the point where lowest altitude is to be crossed. Whenever possible likely crossing clearances to be published with standard routings
(NB: The US plans to introduce vertical navigation in 1977-82. New York already has routes tentatively drawn up.)
3. Intermediate approach speed for radar vectoring to be 200 kts minimum.
4. Whenever possible pilots should be allowed to control their own navigation - including speed - for an approach.
5. Minimum height for intercepting the glideslope, especially over London. to be 3,000 ft preferably higher.
6. DMEs to radiate from all ILS. Pilots to be encouraged to keep aircraft clean for as long as possible, and not to lower gear before about 5 miles DME unless precluded by weather. (The exact point will depend upon the aircraft's gear extension time.)

Assuming —

- a) 1 and 2 allow a modest 15 mile improvement in descent accuracy (assuming aircraft kept clean on reaching lower level),
- b) 3 produces a reduction in 170 kts for 10 miles, allowing aircraft to be kept clean,
- c) 6 persuades pilots to lower their gear 5 miles later : —

The savings for a 747 type of aircraft would be:—

- (a) 325 kgs (90 gals)
 - (b) 200 kgs (55 gals)
 - (c) 200 kgs (55 gals)
- 725 kgs (200) gals total

(NB: It is only too easy to lose 2000 kgs during descent and approach. The fuel burnt on a short sector such as Manchester or Paris to London should only be 8000 kgs).

There were about 120,000 landings at Heathrow last year. Of course they were not all 747s but it might be argued that there's a potential saving of 24 million gallons in the fuel that Heathrow has to provide annually. Even 10% would provide a worthwhile 2.5 million gallon reduction which could certainly be achieved **now**.

NOTE

Continuous Descent Approaches (CDA) from stack level of FL 70 were introduced into LHR in 1975, initial approach speed 210 kts.

DMEs were installed on the ILS in 1978 - funded by the Department of the Environment for noise abatement.

National Air Traffic Services

FROM: Air Commodore Ian Pedder, OBE, DFC, MBIM, RAF,
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The Adelphi,
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NATS

H P K Dibley, Esq,
Guild of Air Pilots and Air Navigators,
163 Holland Park Avenue,
LONDON W11

Our Ref: 8M/52/03 S
7 May 1974

Dear Mr Dibley,

FUEL SAVING

It is with considerable interest that I read your article "How to reduce Noise and Save Fuel – Now" in the March edition of the Journal of the Guild of Air Pilots and Air Navigators.

We are, of course, very conscious of the need to afford operators the opportunity to conserve fuel whenever possible, and we have recently extended the period of operation on the White Airways that we introduced at the beginning of the fuel crisis. These specifically arranged direct routes have enabled significant fuel savings to be made in the en route phase.

The TMA phase has proved to be a more complex problem. I am sure that you are aware that UK controlled airspace is designed to affect the minimum amount of airspace commensurate with flight safety, and this very tight configuration does restrict the room for manoeuvring if we are to avoid any adverse effects upon the expeditious flow of traffic. Even the smallest revisions to procedures can have considerable impact upon other parts of the system. We are currently coming across difficulties in this area and, so far, have not found a solution which could be practically implemented. Nevertheless we shall keep on trying.

Finally, I should like to express my appreciation of your contribution to the problem and reaffirm that NATS is very much concerned to do what it possibly can to offer, to all operators, opportunities to conserve fuel.

Yours sincerely,
Ian Pedder

A Joint Ministry of Defence Civil Aviation Authority Service

Lufthansa Assistance to introduce CDAs

Flight International article in September 1975 describing Lufthansa's Managed Drag procedure for quieter approaches, how DLH were requesting higher vectoring speeds to permit the aircraft to be flown clean for longer during approach, and to delay extension of the landing gear to give minimum drag / thrust / noise.

AIR TRANSPORT

LOW DRAG, LOW NOISE

LUFTHANSA'S "low-drag, low-power" approach technique is at least as safe as traditional approach techniques and the airline believes that its noise-abatement landing scheme has much to commend it. This view was given by Mr Wolfgang Jurzig, chairman of Lufthansa's Noise Abatement Working Group, speaking in London last week. Declaring that noise is currently one of the biggest problems facing his management and that much remains to be done in the control of noise at source, he claimed that the peak of the noise problem has been passed and outlined Lufthansa's contribution to the problem.

Introduction of the quiet, high-bypass-ratio engine had made the noise of earlier engine types more conspicuous. Retro-fitting of quiet engines, nacelles and "hush-kits" is possible but almost prohibitively expensive, so Lufthansa has concentrated on other means of noise reduction. Careful construction of screens and hangars has reduced the number of complaints attracted by engine ground runs.

Noise-abatement departure routes and profiles have been refined, the preferential runway system is used wherever possible, "low-drag, low-power" approaches are now standard practice and the use of reverse thrust during the landing run has been minimised.

Capt Robert Salzl, chief pilot of the Lufthansa Boeing 727 fleet, explained the "low-drag, low-power" concept. Claiming a 50 per cent noise reduction during the intermediate approach (up to the outer marker), he noted that the International Air Transport Association had recommended the technique to all its members in 1972. The height at which the aircraft is required to be fully stabilised, with undercarriage and flaps down, is held down to about 1,000ft. Descent to within 3,000ft of touchdown is "clean," using idle power and optimum speed for the aircraft type. Below 3,000ft speed is reduced to 160-170kt, with flaps around take-off setting and being power set to maintain speed. Descent is continued at this speed. The glidepath is intercepted and followed to a height of approximately 500ft above normal height for crossing the outer marker. The undercarriage is now lowered, the flaps are further extended and power is increased, so that the aircraft is stabilised in the landing configuration on passing the outer marker. Considerable noise alleviation is gained up to the outer marker, but beyond this point no reduction is achieved. To be fully effective, close co-operation with air traffic control is necessary, and preferably all aircraft should fly the same technique.

At Frankfurt Airport, a particular problem has been the city of Offenbach situated close by. Conventional measures for a reduction of noise were insufficient and Lufthansa played a leading part in a study of more radical methods. Pan Am, Swissair and British Airways

FLIGHT *International* 25 September 1975

also worked with the German airline, the Frankfurt airport authority and others to devise low-noise arrival and departure routes. The Frankfurt approach procedure now allows use of the Lufthansa technique and requires captains unable to adhere to the procedure to declare their difficulties.

At London Heathrow, said Capt Salzl, a relatively low speed, (and therefore partial flap and more thrust), is required at distances up to 40 n.m. from touchdown.

Recently, he said, London Control has requested higher speeds (210kt) closer to the airport. From Lufthansa's point of view this is helpful and allows the airline to utilize its "standard" arrival profile to the benefit of the community beneath, as well as to reduce night time and fuel consumption.

Capt Salzl spoke of the Frankfurt environmental protection contest. Aircraft certificated to ICAO Annex 16 noise standards and using the Frankfurt approach technique are awarded points (according to the weight of aircraft) for each arrival; in November, DM2-5 million will be distributed to the airlines according to the points gained.

• Recent comment in the local press near Heathrow indicates that Lufthansa's low-drag, low-power technique has attracted the attention of sharp-eyed residents. The British Civil Aviation Authority told an enquirer that, using Lufthansa's technique, "there may be an erosion of safety margins." The CAA has not published any facts to back up this assertion, which not surprisingly received widespread coverage in the local press. Flight is told that the CAA's Directorate of Operational Research and Analysis reports that "Lufthansa's Boeings are no quieter than any others," but the CAA has neither commented on the noise levels of different approaches nor said where its measuring point or points were. Flight understands that the CAA is "against the procedure in principle because it changes standard procedures."

British Airways' Tridents in particular require long, relatively slow, approaches using automatic landing and autothrottle. It appears that Heathrow traffic patterns have been drawn to accommodate them.

The Overseas Division of the airline, however, is fully aware of the benefits to be gained from such techniques and independent of Lufthansa, a British Airways 747 captain has produced a circular slide rule for use during descent, so that the descent point can be accurately predicted and frequent checks easily made during descent. Not only is the resulting arrival quicker but it saves a considerable amount of fuel—savings of perhaps £50 can be made during a 747 approach.

From a pilot's point of view these techniques are attractive in reducing an often familiar "drag round the houses," and Lufthansa reports no adverse comment from its pilots using revised check lists with the technique.

Airport noise

The German way

A technique which could halve aircraft noise for people living under the landing route more than 3-4 miles, from London's Heathrow airport (say Westminster to Chiswick) is being given the cold shoulder by the Civil Aviation Authority. The technique, called "low-drag-low-noise", was developed by the West German airline, Lufthansa, to get round a problem with a small village directly in line with the runway at Frankfurt airport, where the residents were objecting to having their eardrums blasted. What it adds up to is that Lufthansa is leaving the noisy, final, bit of the landing process until its aeroplanes are nearer the airport and (don't get alarmed) nearer the ground.

Under both the Lufthansa and the standard systems, air traffic controllers direct the aircraft, flying at about 210 knots, towards a point about 14 miles from the runway to intercept a theoretical glide path which points up from the end of the runway at 3°. Using the conventional landing approach, at about 12 miles from the runway the undercarriage and flaps are put down, which means that power and noise are created. The aircraft flies in, slowing down to about 140 knots in this configuration, until it lands. On a fine day Lufthansa aircraft, by contrast, come in on minimum power at 170 knots all the way, no flaps, no wheels: these are then put out in time for the aircraft to be stabilised before reaching 1,000 feet (or higher if the weather is less good).

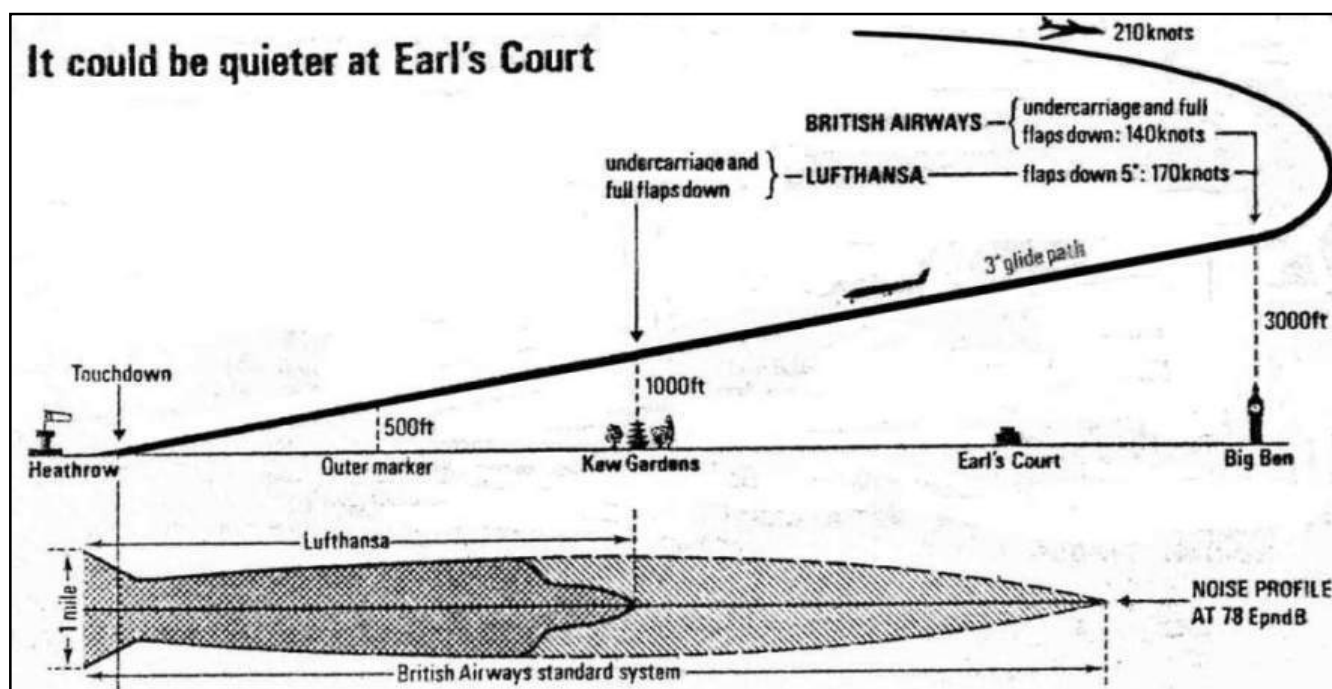
As well as making less-noise Lufthansa, reckons that it is now saving an average of 30 gallons of fuel on each landing by its Boeing 727 aircraft and on reduced maintenance. Less throttle is needed to push the aeroplane along when it does not have the wheels down and all those flaps (wing extensions which give more lift) hanging about.

The British concern about the new technique is said to centre on safety—in particular, whether the system increases the pilot's workload during landing, the most dangerous part of the flight. Yet British Airways pilots helped devise the new technique and it has been welcomed by the pilots' international association, Ifalpa. (The pilots are less happy about an American development, called the two-segment approach, where the aircraft first descends down a 6° slope, to intercept the 3° glide path not far from the outer marker.)

Your special correspondent can vouch that the crew seemed to have more than adequate time during a recent low-noise approach to Heathrow in a Lufthansa 727. The three minutes or so between putting out the undercarriage and flaps and landing were more than adequate for the crew to go through its final checks that all was well (and for the captain to double-check).

The real reason for British official apathy may be a clash with the automatic landing system used on British Airways Tridents. This requires the undercarriage and flaps to be lowered miles out as in the standard technique.* This is fine when the weather is foul (BA can land at Heathrow when most others cannot). But people who live from Westminster to Chiswick (and similar places around other airports) deserve better treatment when the weather is better, which is

* BAOD B747s also had Cat3A autoland capability to land in fog but could still fly low-drag-low-noise descending approaches.



OBSERVER 21st September 1975

'Gliding' Jets halve the noise

By ANDREW WILSON

BRITISH AIRWAYS and the Civil Aviation Authority are resisting introduction of a landing technique that could cut London and other cities airport noise by half.

The technique, known as 'low drag, low power,' has been safely and successfully used by the German airline Lufthansa for more than four years.

Instead of putting out flaps and landing gear 12 miles from the runway, and having to increase power and noise to overcome the extra drag (the conventional British Airways method), Lufthansa pilots fly 'clean' down the three degree glide-slope until they are near the airport.

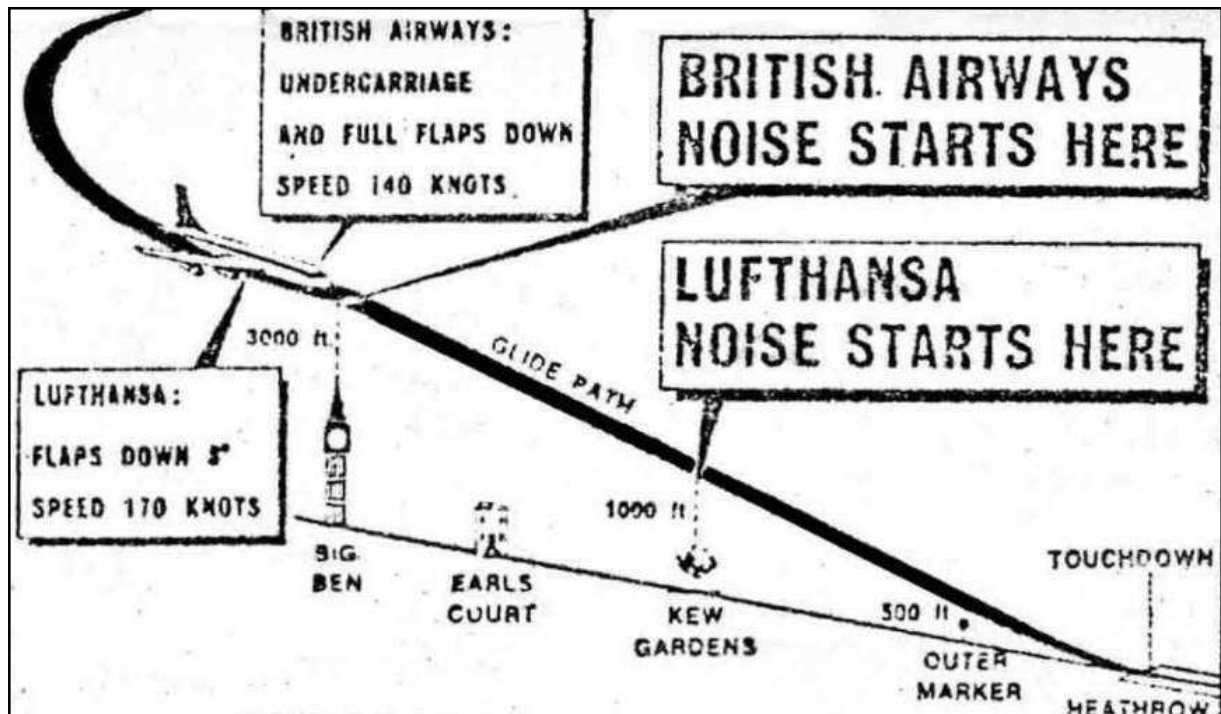
At 1,000 feet they still have 40-50 seconds to extend flaps and gear and (stabilise for the touch-down. If that were allowed when approaching Heathrow, thousands of people living along the Thames would be spared ear-splitting noise.

At a discussion in London last week CAA officials alluded to air traffic control problems with the German system. But the real reason for Britain's reluctance is that British Airways Tridents, already among the noisiest jets in the world, are equipped with an automatic landing system which requires that flaps be extended at conventional height.*

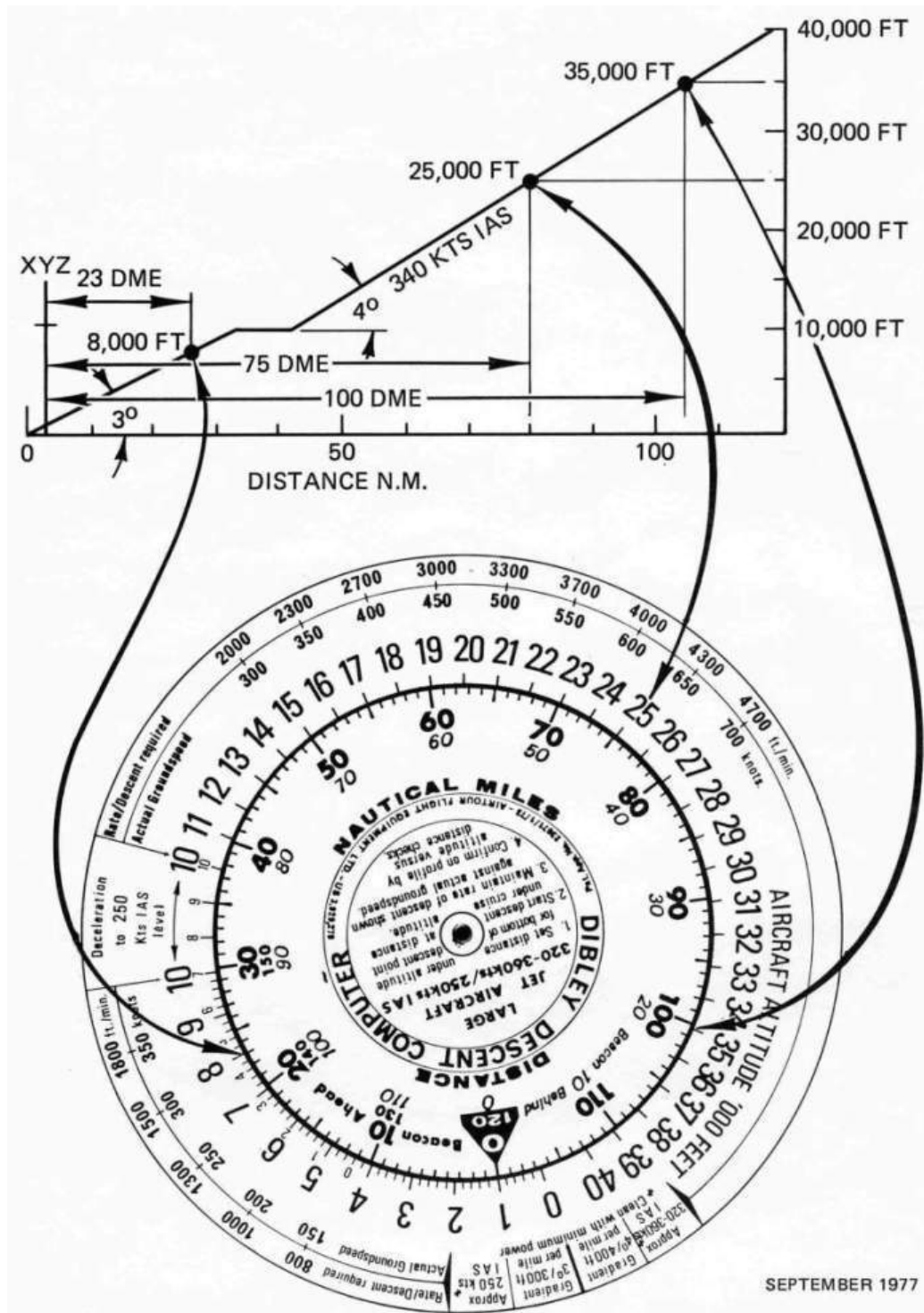
The British planes descend at 140 knots (161 m.p.h.), spreading a carpet of noise over a wide area, whereas Lufthansa's Boeing 727s descend at 170 knots, with engines nearly idling, almost like gliders. Even at Kew, where noise would begin, (see diagram) it would be much reduced.

Lufthansa's technique has been recommended to member airlines by the International Air Transport Association.

* BAOD B747s also had Cat3A autoland capability to land in fog but could still fly low-drag-low-noise descending approaches.



'Flaps out' at the last minute. How Lufthansa's way could save London's ear drums.



Dibley Descent Computer Set to Cross 23 n miles DME from XYZ at 8,000 ft and 250 kts IAS

(Artwork by Lockheed, Burbank, for L1011 / TriStar Operators' Conference, September 1977)

Start descent from FL 400 at 113 DME n miles

At Sink Rate for Groundspeed:

3,700 fpm for 550 kts; 3,300 fpm for 500 kts; 3,000 fpm 450 kts, etc

Continuous Cross-checks to confirm on profile – e.g.

At 100 DME should be at FL 350

At 75 DME should be at FL 250

At 59 DME should be at FL 185, etc