Further written evidence from NATS (AS 51B)

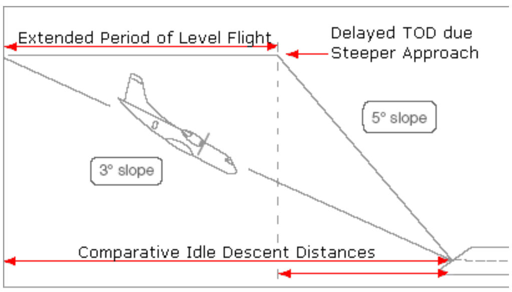
During the Committee's oral evidence session on Monday 10 December, Simon Hocquard, Operational Strategy and Deployment Director for NATS, agreed to send the Committee information on the impact on fuel burn of steeper approaches and steeper departures.

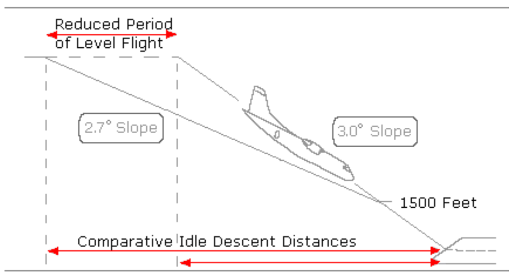
Steep Approaches

The following details are taken from manufacturer and airline supplied data and flight simulations which NATS commissioned as part of a Research & Development study on Steep Approaches. The Committee should be mindful that the data is therefore caveated that the simulations by their nature are subject to inaccuracies in both the data provided by the manufacturers and by the airline participants themselves. However, we believe they are indicative.

The first image below illustrates that flying in a straight line to the start point, or 'Top of Descent' (TOD), for a steeper approach, the aircraft will spend longer in level flight to reach that point. The extra fuel burn as a result of this extended period of level flight is added to the calculations below.

The second image below illustrates the GE view of a segmented approach; steeper to 1500ft and then a transition to a 3 degree approach.





Boeing 737 (B737)

GE, a manufacturer of aircraft Flight Management Systems for Boeing, supplied NATS with the following data for the latest B737 aircraft. GE state that 2.7° is the optimum approach angle for fuel burn for this type of aircraft, and above that fuel burn increases. The table below sets out the potential increases for a range of steeper approaches.

Descent Angle	Increased Descent Fuel Burn	Increased Level Distance Flown	Increased Level Distance Fuel Burn	Total Fuel Burn (Descent from 10,000ft)
2.7° (Baseline)	0	0	0	138.0kg
3°	44.0kg	3.5nm	27.4kg	209.4kg
4°	55.4kg	11.36nm	88.8kg	282.2kg
5°	63.1kg	16.09nm	125.8kg	326.9kg

Airbus A380

The following data, supplied by an airline, shows the projected fuel saving benefit to all angles steeper than the standard 3 degrees for the Airbus A380. The tables show reduction in fuel burn resulting from a range of steeper approach angles (Table 1), while Table 2 includes the extra fuel burn as a result of the additional time spent in level flight segment.

Table 1

Approach Angle	Total Fuel Burn	Total CO_2
3°	395kg	1234.8kg
4°	236kg	743.4kg
5°	152kg	478.8kg
6°	92kg	289.8kg

Table 2

Approach Angle	Descent Fuel	Level Flight Fuel	Total Fuel
3°	395kg	0kg	395kg
4°	236kg	171kg	407kg
5°	152kg	275.9kg	427.9kg
6°	92kg	342.6kg	434.6kg

The results show that, taken in isolation, steeper angles of approach can reduce fuel burn, across most aircraft types. However, the increased time spent at level flight, required to reach the delayed TOD, and factors such as the wind conditions, erode any benefit in terms of fuel savings from steeper approaches, and, as demonstrated in the examples given, can lead to increases in the overall fuel burn.

NATS believes it is possible to optimise the level flight segment by employing other methods to achieve the potential fuel saving benefit of steeper approaches, although we have yet to undertake any work in this area.

Other Points to note:

- Aircraft ability to perform steeper approaches in low visibility conditions, using auto land capability, is limited to 3.25° for the majority of aircraft types.

- At London City Airport, where steeper approaches are in use given its geographical location, crew require on-going checks and must fly the approach regularly to stay 'current' and legal. Aircraft may also require special adaptation, as is the case with the Airbus A319.

- Several airports in the UK already use a 3.5° approach and, as mentioned above, London City Airport uses 5.5°.

- Approaches are classified as follows:
  - 3° to 3.5° - normal
  - 3.5° to 4.5° - permission required from the aircraft manufacturer to state that this operation is within the limits of the aircraft's capability
  - 4.5°+ is considered by ICAO to be a steeper approach

Noise

As Simon Hocquard explained in the Committee's evidence session, the anticipated benefits associated with steeper approaches are mainly related to reduced noise impactsfurther away from the airport. Steeper approaches would offer little benefit in noise levels close to airports.

We should point out, however, the International Civil Aviation Organisation (ICAO) policy on approach angles:

'For precision approaches, glide path angles above 3.5° should be used in approach procedure design only for obstacle clearance purposes and must not be used as a means to introduce noise abatement procedures. Such procedures are non-standard and require a special approval'.

While noise can be reduced when the entire approach path is taken into consideration, the issue is one of energy management for the aircraft. In order to remain within required speed limits, the aircraft is likely to deploy more wing surfaces (slats and flaps) and the undercarriage earlier. This may generate greater peak noise than a 3° approach at certain points along the approach path, where they are deployed.

The following table is an extract from an ICAO document which details the noise reduction to be achieved across a range of aircraft types at varying steeper approach angles.

Aircraft Type	Contour Level (dBA Sound Exposure Level - SEL)	3.25°	3.50°	3.75°	4.00°
A340-600	75	-4%	-8%	-12%	-16%
	80	-7%	-16%	-26%	-35%
	85	-8%	-17%	-28%	-39%
	90	-10%	-19%	-26%	-32%
B737-800	75	-4%	-8%	-14%	-21%
	80	-9%	-17%	-24%	-30%
	85	-2%	-6%	-9%	-14%
	90	-9%	-17%	-24%	-29%
B777-200	75	-7%	-13%	-20%	-25%
	80	-6%	-12%	-17%	-21%
	85	-7%	-11%	-14%	-18%
	90	-5%	-9%	-12%	-15%

Steeper Climb Outs (High Performance Departures):

A procedure that is predicated on an aircraft climbing more steeply than the currently accepted 'normal' gradient (5.75%) is now known within NATS as a High Performance Departure (HPD).

Work completed by NATS, on behalf of Heathrow Airport, as part of the Department for Transport (DfT) sponsored *Project for the Sustainable Development of Heathrow (PSDH)* identified HPDs as offering potential capacity benefits through improved airspace design. The proposed HPDs would see aircraft departing on specified Standard Instrument Departures (SIDs) where the climb gradient required was steeper than the then accepted practice.

Research conducted by NATS and British Airways on the optimum vertical profile and the details of the flight trials published as *'The Perfect Flight'* (for an A319) indicates that the most efficient profile is steeper than that currently stipulated as the minimum gradient on most SID plates.

The 'Perfect Flight' concept might deliver steeper departure profiles, but it is possible that the airspace design for a multi-airport Terminal Manoeuvring Area (TMA), such as London, will require even steeper profiles in order to maximise airspace capacity. Steep departure profiles require the aircraft to climb even faster than is optimum to provide separation from other routes and airfields. Although these departures will not be suitable for all aircraft, early indications are that they may still deliver fuel burn and CO_2 efficiencies as the aircraft reaches a higher altitude more quickly.

Increased gradients already exist on SIDs and are routinely flown today from some airfields. These increased gradients are currently required for the purposes of obstacle clearance. However there is industry acceptance of the fact that the performance and efficiency of aircraft flying today far exceeds that on which procedure design guidance was predicated.

Factors Affecting Fuel Burn (Take-off/Climb Out):
According to Airbus, there are many variations in take-off technique that can directly affect the fuel burn. In general the effects are dependent on the airframe/engine combination as well as

aircraft weight, airfield elevation and temperature as well as the operating procedures of the crew.

NATS & Airline Trial at Stansted:
An HPD trial was conducted at Stansted Airport on an Amsterdam route; post-trial the airline and the airport requested that such arrangements be made permanent as they recognised fuel burn and noise reduction benefits.

The charts below provide indicative fuel burn of an aircraft on a standard departure and for an HPD trial. These are indicative - the actual fuel figures across all flights varied considerably. They demonstrate that a fuel burn saving comes from consideration of the entire flight path, including cruise and arrival and not just the departure phase. Aircraft climbing more quickly to a higher altitude are able to maximise the benefits of more efficient fuel burn at cruise altitude.

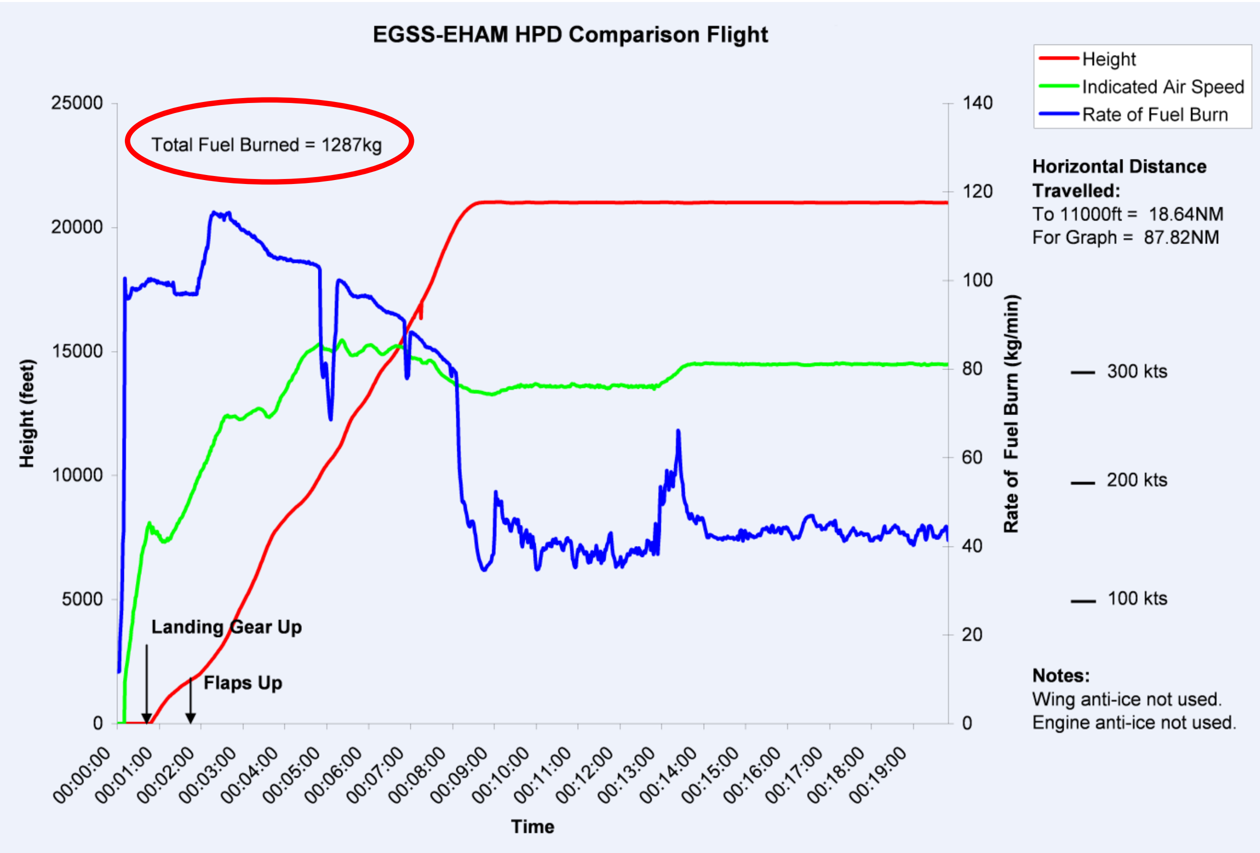


Figure 1: Non-HPD Base Line Flight

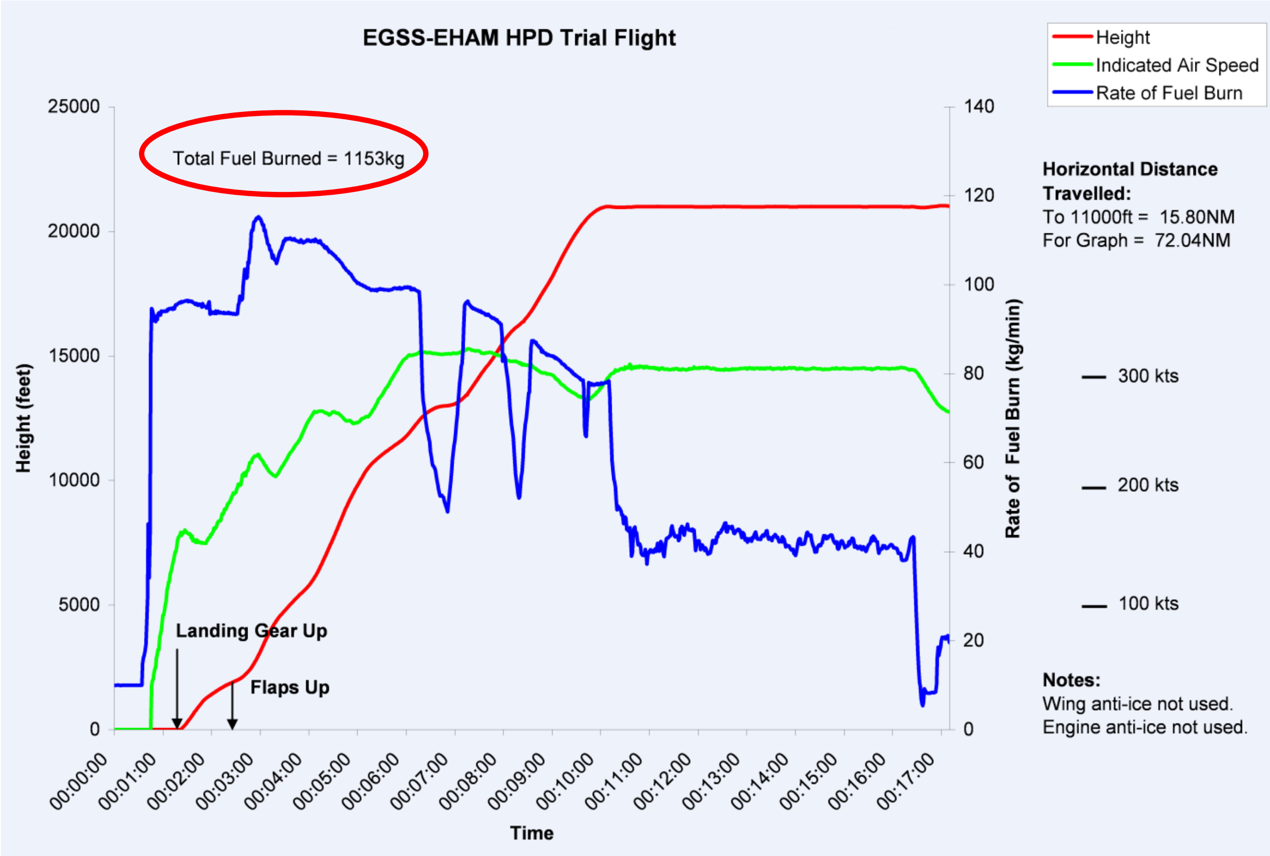


Figure 2: HPD Trial Flight

The results are indicative of the possible benefit of HPDs, but many factors exist which may not have been taken into account in this limited study. These factors would need to be thoroughly examined with more samples before a definitive conclusion could be drawn. However, on the basis of this limited trial, the following initial conclusions can be made:

- The minimum rate of fuel burn for aircraft participating in the trial increased by 10.44kg/min (or 2%) however the maximum fuel burn was reduced by 0.55kg/min or just over 1%. The average rate of fuel burn for aircraft participating in the trial increased by 2.64kg/min, or 0.54%.

- The minimum time taken for aircraft to reach FL110 by aircraft participating in the trial increased by 1 minute 50 seconds while the maximum time taken to reach FL110 reduced by 27seconds. Overall the average change to the time taken to reach FL110 was a reduction of 9 seconds.

- The overall minimum fuel burnt by aircraft participating in the trial was reduced by between 1 and 6%.

1 February 2013