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Environmental Impacts of Aviation

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Greener by Design Initiative (launched March 2000)

Objective: To assess and promote options for mitigating the environmental impacts of aviation

Founders: Royal Aeronautical Society
Society of British Aerospace Companies
British Air Transport Association
Airport Operators Association
Department of Trade & Industry

Sub-Groups: Technology/Operations/Market-Based options

GBD now an independent specialist group of the RAeS

Altra Capital

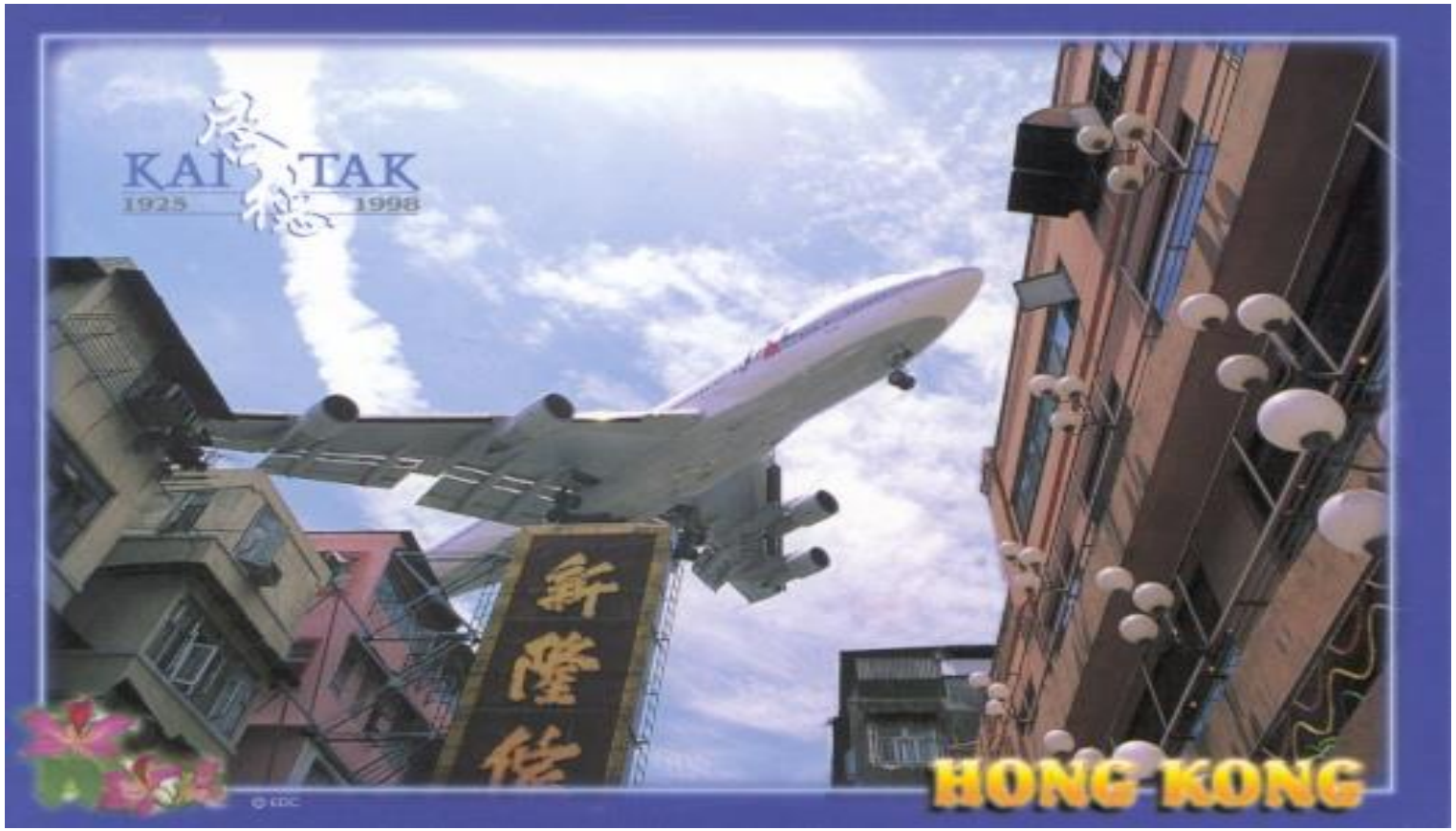
- High level independent Management & Advisory Group
- Review, design, implement and manage Strategic projects
- Focus on designing and financing Infrastructure projects, especially in the aviation sector
- Specialists in Training and Knowledge Exchange
- Ethical approach to business underpins what we do
- Much of our business is in the Middle East, South America and Africa
- Offices in London, Lima, Jeddah and Kuwait

Environmental Impacts of Aviation

Three Key areas:

1. **Noise**
2. **Air Quality**
3. **Climate Change (Greenhouse Gases)**
4. Land Use - Biodiversity/Water & Flood risk/Place/Quality of Life/Community

Final Approach at Kai Tak (closed 1998)



1.1 Noise – What is it?

- **Energy** propagated by air waves
- Causes fluctuations in pressure
  - Detected by ear / microphone
- Individuals have different sensitivities to noise
- Noise is unwanted sound (WHO definition)

1.2 Noise and Distance

- Focus is on received *not* emitted sound
- Energy reduces in inverse square proportion to distance
- In practice, also absorption and dissipation
  - Faster fall off
  - Also affected by Temperature and Wind Speed (which also causes noise)

Human ears have evolved to reduce sensitivity to very loud noises and increase sensitivity to quiet noises – so although noise energy has (say) halved, we detect considerably less reduction. Converse is also true!

2.1 Measurement I

- Sound is complex so different scales used to catch different aspects
- Commonest measure is dB(A)
- *Weighted* to reflect the human hearing (denoted by A)
- *Logarithmic* scale – so +10dB is a 10 fold increase in energy
- Duration is important – how long does the noise last?
- And so is the time of day, or night
- The *maximum* noise is also important
- Some measures average the noise out over a defined period, say 0700 – 2300 (equivalent noise levels - Leq)

2.1 Measurement II

Other measures in use

- **Maximum perceived sound level** **LA_{MAX}**
- Sound exposure level SEL
  (Event normalised to 1s burst of sound)
- Perceived (by humans) Noise level PNL
- **N Contours(> 70dbA day)** **N70**
- **Equivalent continuous sound level** **LA_{EQ}**
- **LA_{EQ} weighted over 24hours (+5/10dB)** **LA_{DEN}**

2.2 dB(A) Noise Examples

- Normal conversation 50-60 dB(A)
- Quiet countryside 30-40 dB(A)
- Loud radio 65-75 dB(A)
- Busy street 75-85 dB(A)
- Heavy lorry 7 metres away 95-100 dB(A)
- Chain saw 115-120 dB(A)
- Jet aircraft taking off 25 metres away 140 dB(A)

2.3 Time averaging

- One 77dB(A) event every hour
- One 67dB(A) event every 6 minutes
- One 57dB(A) event every 36 seconds

Are all equivalent, and will give the same $dBLA_{eq}$ value

Individuals are affected differently

- AND depends **what** you are doing - noisy/quiet
- AND depends on **where** you are doing it - outside/inside
- AND depends on the **ambient noise level** - noisy/quiet

2.4 N Contours

Capture how many times (day or night) a location is exposed to a particular decibel event *(>70dB day/60dB night have been used by the Airport Commission*)

- No Weighting
- Counts events over defined period
- Use is relatively new (used for Sydney Airport, now LHR)
- Presented as contour maps
- *AC Report uses Histograms of the population exposed to any events > X dB*
- ***Use in conjunction with other measures***

3.1 International Legal Noise Limits (Chapters)

Aircraft must meet International standards, which have been progressively tightened from original Ch1 aircraft

1990

- All Chapter 2 Aircraft to be withdrawn by 2002 or fitted with hush kits

2001

- Chapter 4 - introduced from 1/1/06 (High bypass ratios)

2013

- Chapter 14 – Newly designed high weight aircraft from 31/12/17 (LW from 2020) (includes CO2 standard)
  - Today all Chapter 3/4/14 aircraft

3.2 ICAO 'Balanced Approach' (4 pillars)

Cost effective balance of four issues

- Make aeroplanes quieter by setting noise standards
- Adapting operational procedures to reduce noise impact on the ground (abatement)
- Managing land around airports in a sustainable way
- Introducing operational restrictions

Incorporated in EU Legislation (EC/2002/30)

Which also provides rules for withdrawing marginally compliant aircraft

4. Noise Abatement and Mitigation

4.1 Aircraft Operations
- Techniques for operating aircraft more quietly

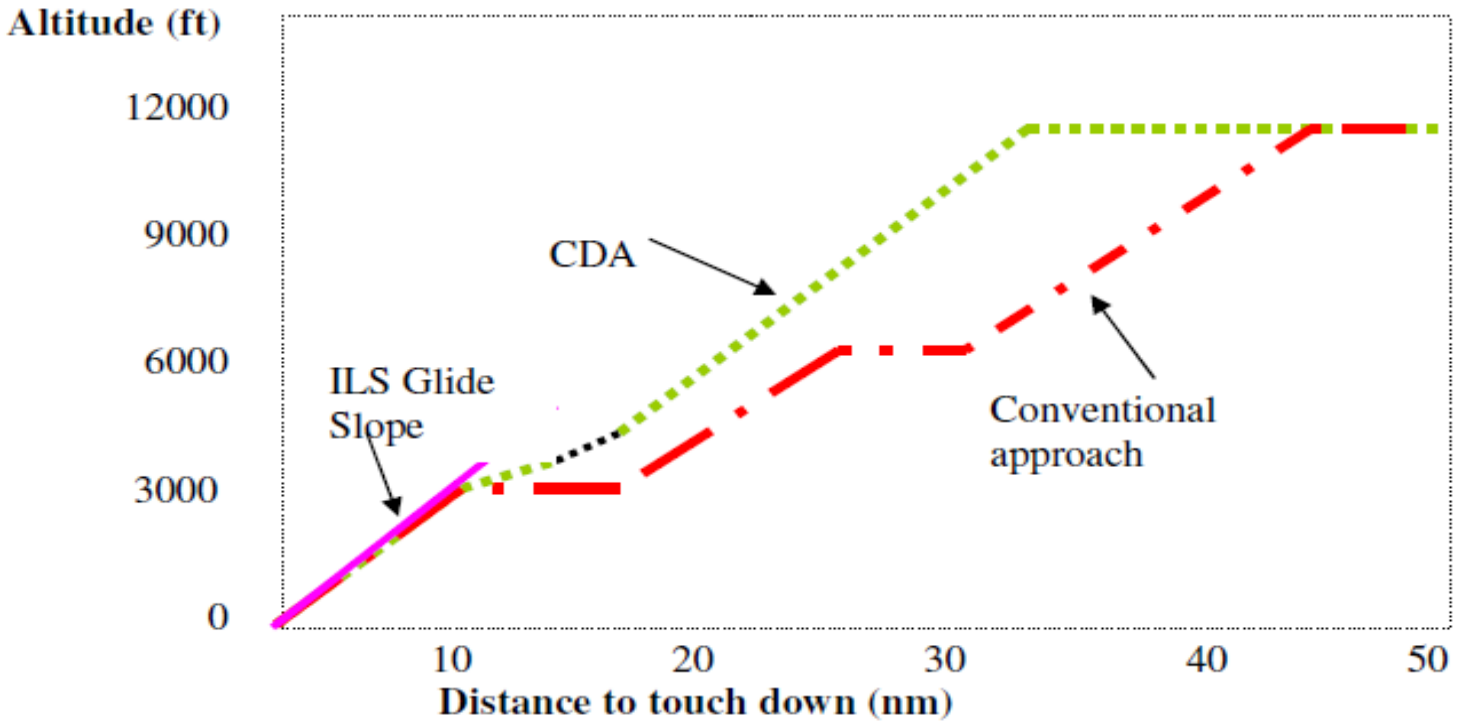
4.2 Aircraft Design
- Reducing engine & airframe noise

4.3 Airport Issues
- Reducing noise at Airports

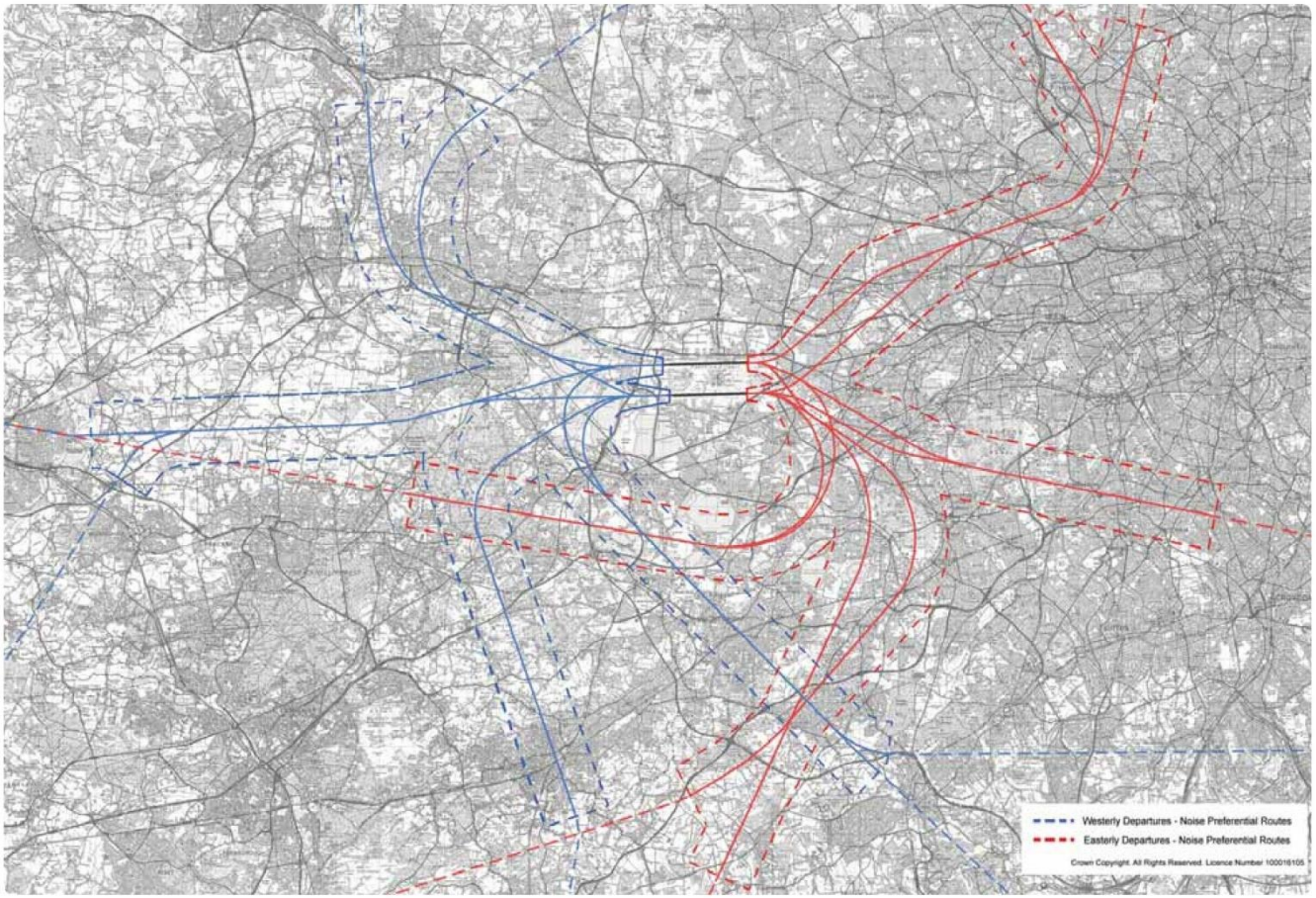
4.1 Aircraft Operation

- Continuous Descent/Climb
- Low power/low drag ascent
- Cross wind/tail wind landing (5 knots)
- Noise preferential routing (NPR)
- Displaced threshold
- Steeper/curved approaches
- Runway preference/rotation (if multiple runways)
- Noise dispersal - new routes
- Noise dispersal on existing routes (3km wide)
- Respite

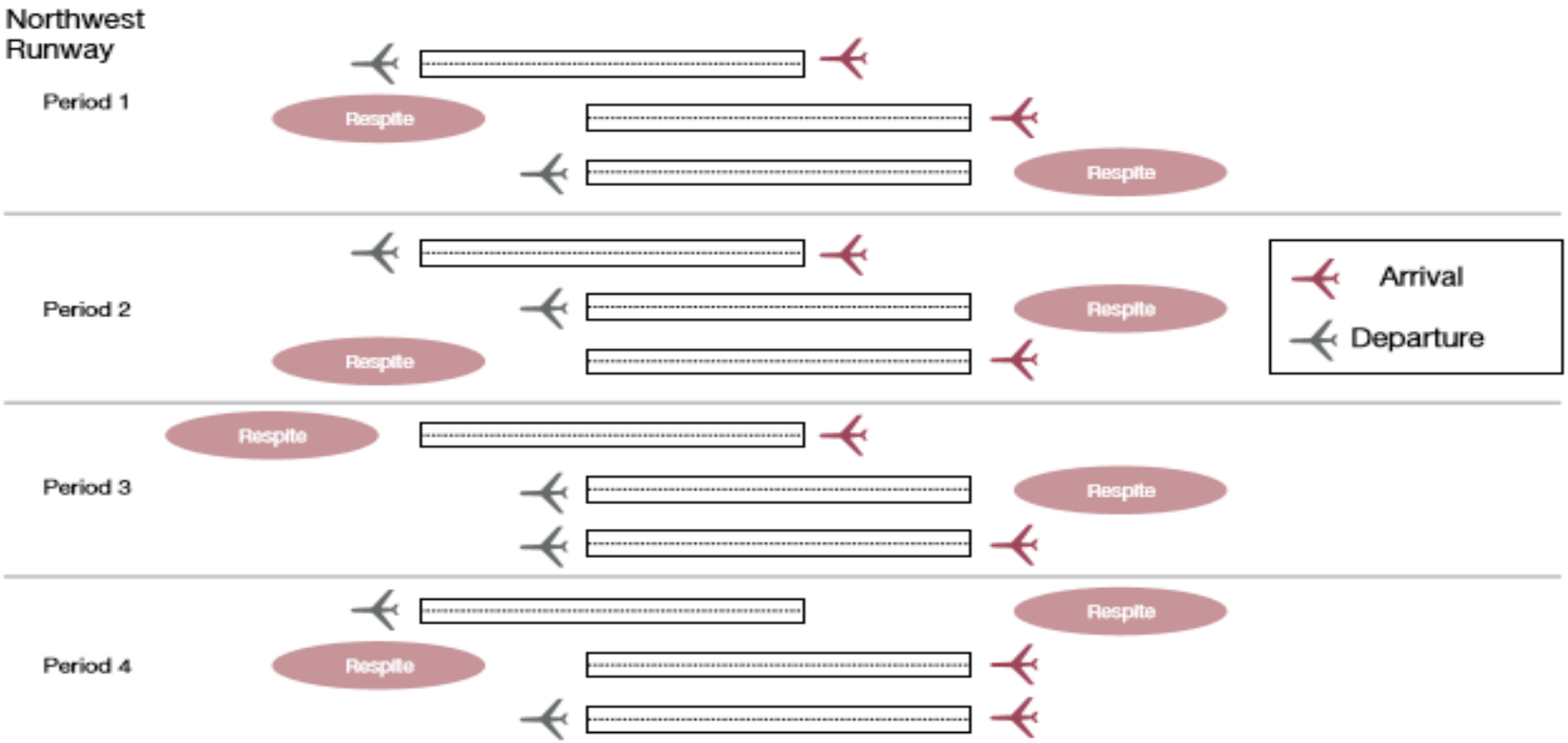
Continuous Descent Approach



LHR: Noise Preferential Routes (2008)



LHR respite periods (AC Final Report)



Source: Airports Commission analysis

Conclusion - Operations

- Many significant opportunities for noise abatement now
- Air Space re-design necessary for CDA/NPR/Steeper approaches
- Aircraft design / Certification issues
- Pilot / ATC training
- Paramount importance of safety

With quieter aircraft, possible to maintain/improve noise contours in the future despite more flights

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4.2 Designing for Reduced Noise

- Sources of noise
- Trade offs
- Noise reduction targets
- Engine design improvements
- Silent Aircraft initiative
- More revolutionary ideas

4.2.1 Sources of Aircraft Noise

- Engine
  - Fan inlet
  - Fan exhaust
  - Compressor
  - Combustor
  - Turbine
  - Jet Exhaust
- Airframe
  - Wings
  - Flaps
  - Slats
  - Undercarriage
  - A320 Fuel tanks +U

NOTE: Airframe noise dominates landing

4.2.2 Design Trade-Offs

- Increase in engine bypass ratio
  - Improves fuel economy
  - Reduces noise

Noise also reduced by:

- Acoustic liners in intake ducts of the fan
- Mixer jet exhaust nozzles
  - Give weight & performance penalty
  - Reduces fuel economy

  Also higher engine temperature increases efficiency but at the cost of increased NOx production

4.2.3 ACARE Noise Reduction Targets

In a vision for 2020, published 2002

- Reduce external noise by 50%
  - Not legally binding, but strong pressure to achieve
- Similar NASA target

In Flightpath 2050, published 2011

- Reduce perceived noise by 65% cf new aircraft 2000

Advisory Council for Aeronautical Research in Europe

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4.2.4 Noise reduction on RR Trent Engine

- Advanced low speed fan
- Rotor assembly process
- Spliceless fan case liner
- Spliceless intake liner
- Handling bleed silencing
- Advanced LP turbine (containing tones within turbine)
- Maximised and optimised acoustic liners
- Advanced swept outlet exhaust (re-phasing of sound field for acoustic reduction)

Source: Rolls Royce

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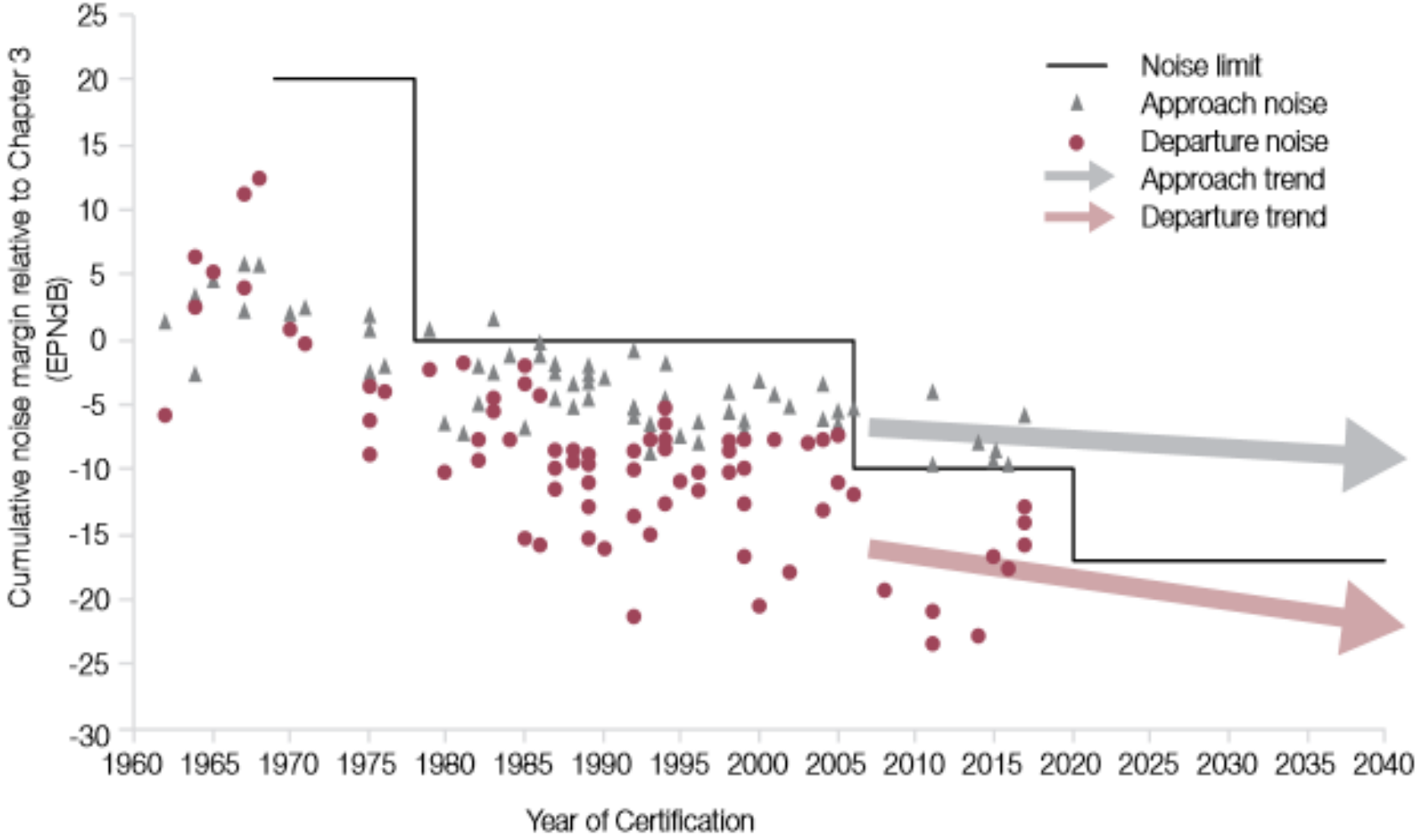
Figure 9.1: Historic and future trends in cumulative certificated aircraft noise levels from noise discussion paper, 1960-2040



4.2.5 Silent Aircraft Initiative I

- Joint Cambridge University/MIT Institute
- Restrict noise to 57 dBA outside airport boundary

  (assumed to be 1 km all round runways)

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4.2.5 Silent Aircraft Initiative II

- Overwing engines
  - Uses Aircraft as shield
- Large blended wing body
  - less obvious fuselage/wing split
- Quiet lift/drag generation
- Active laminar flow control
- Shielded undercarriage

4.2.5 Silent Aircraft Initiative III

- Reduce jet exhaust velocities
  - large increase in bypass ratio (Noise proportional to 8^{th} power of speed, but only linearly to jet exit area)
- Reduce landing speed
  - (noise proportional to 5^{th} or 6^{th} power of speed)
- Achieves noise objective BUT
  - only 25% reduction in CO_2
  - not ACARE compliant

4.2.6 More revolutionary ideas

- Geared fan
- Electric aircraft (hybrid)
- Morphing wing structure
- 3D printing (intricate shapes without joints)

4.3.1 Airport Noise Reduction Techniques

1. Land use
2. Noise insulation
3. Bunds
4. Fixed Electrical Ground Supply (avoids APU use)
5. Airport layout
6. Engine out taxi
7. Electric powered taxi-ing
8. Access

4.3.2 Airport Noise Action Plan - LHR

- Quietest fleet possible – *charges/ban noisier aircraft*
- Quietest practical operation – *fines/night cargo ban/name & shame*
- Effective Noise Mitigation schemes - *insulation*
- Engage with affected communities - *consultation*
- Influence planning policy – *publish noise contours*
- Organise to manage noise – *noise management systems*

→ With quieter aircraft, possible to maintain/improve noise contours in the future despite more flights *but trade offs with jobs/ancillary activities remain*

5.1 Summary - Upsides

- Planes much quieter today
- 20dBA reduction from mid 1960s to 1990s
- Observed as 75% cut in noise
- In physical terms only 1% of energy present
- Fleet replacement will give noise reduction in the future
- Many new possibilities for noise reduction