



# Departure noise optimisation

Preliminary results

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# Objective & results

## Objective

Reduce departure noise based on LA<sub>max</sub> as much as possible for the largest population (and SELs where possible), while minimising negative effects including increased noise, NO<sub>x</sub> and fuel burn.

Loudness of noise event



Total noise exposure of noise event, includes duration



## Results

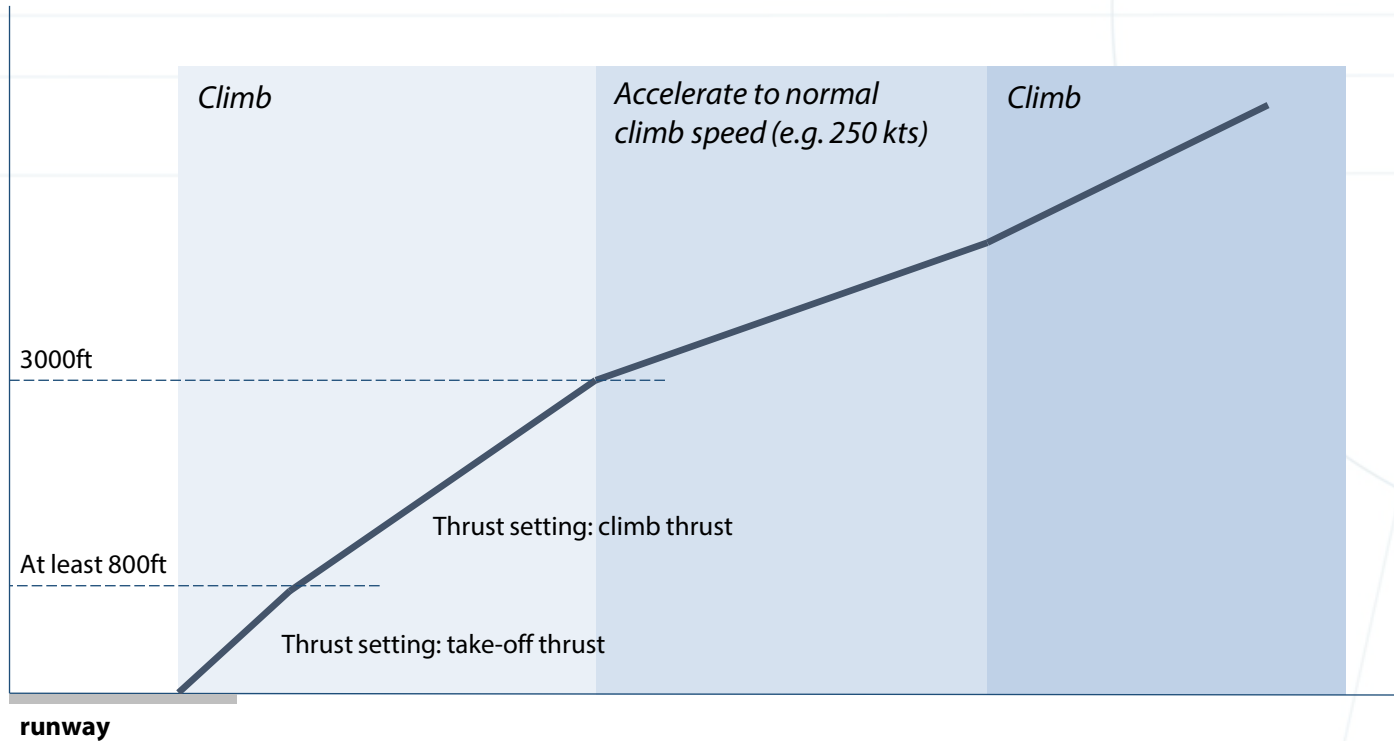
Significant potential to reduce departure noise for A320 aircraft based on both LA<sub>max</sub> and SELs for 60+ dB area:

- Change from NADP 2 to NADP 1
- Preferably, increase acceleration height

Further reductions in noise possible by increasing T/O thrust

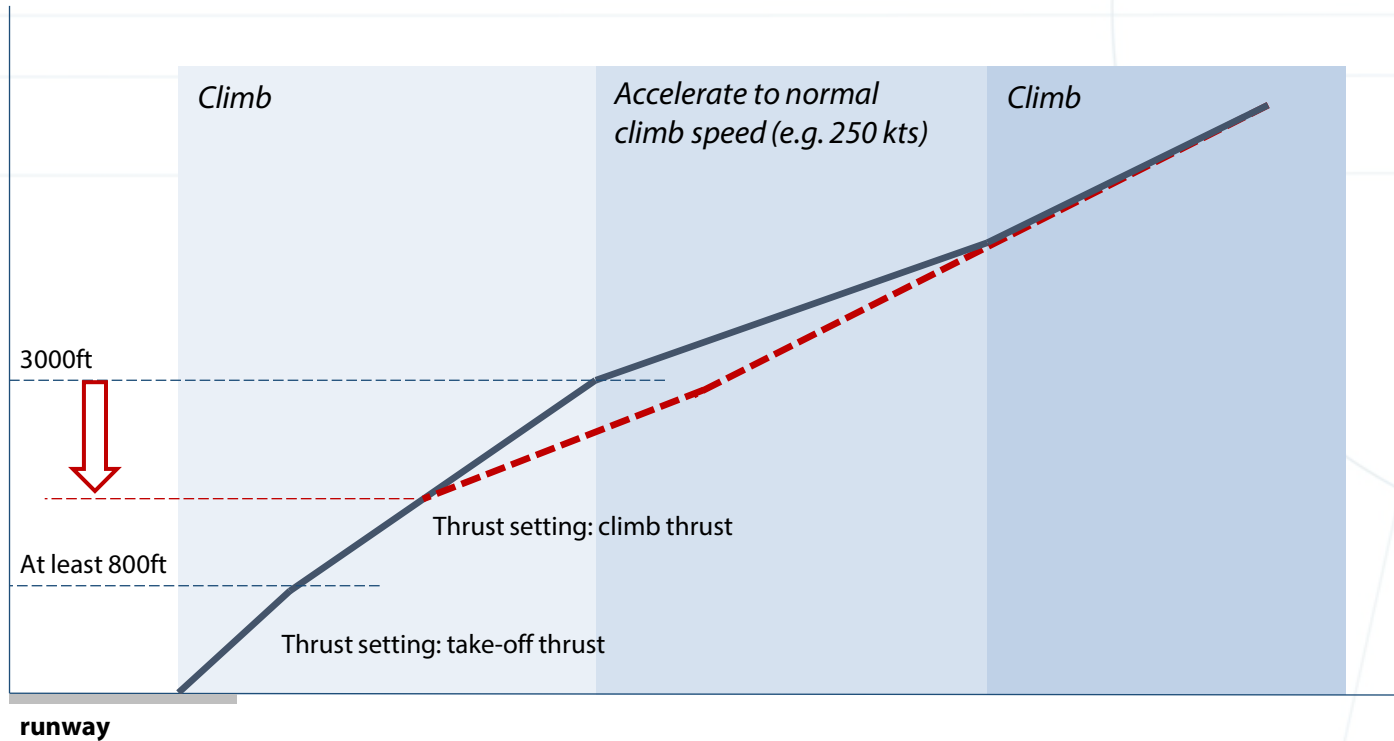
# What is a departure procedure?

Example: Noise Abatement Departure Procedure 1 (NADP1)  
(defined by international guidelines)



# What is a departure procedure?

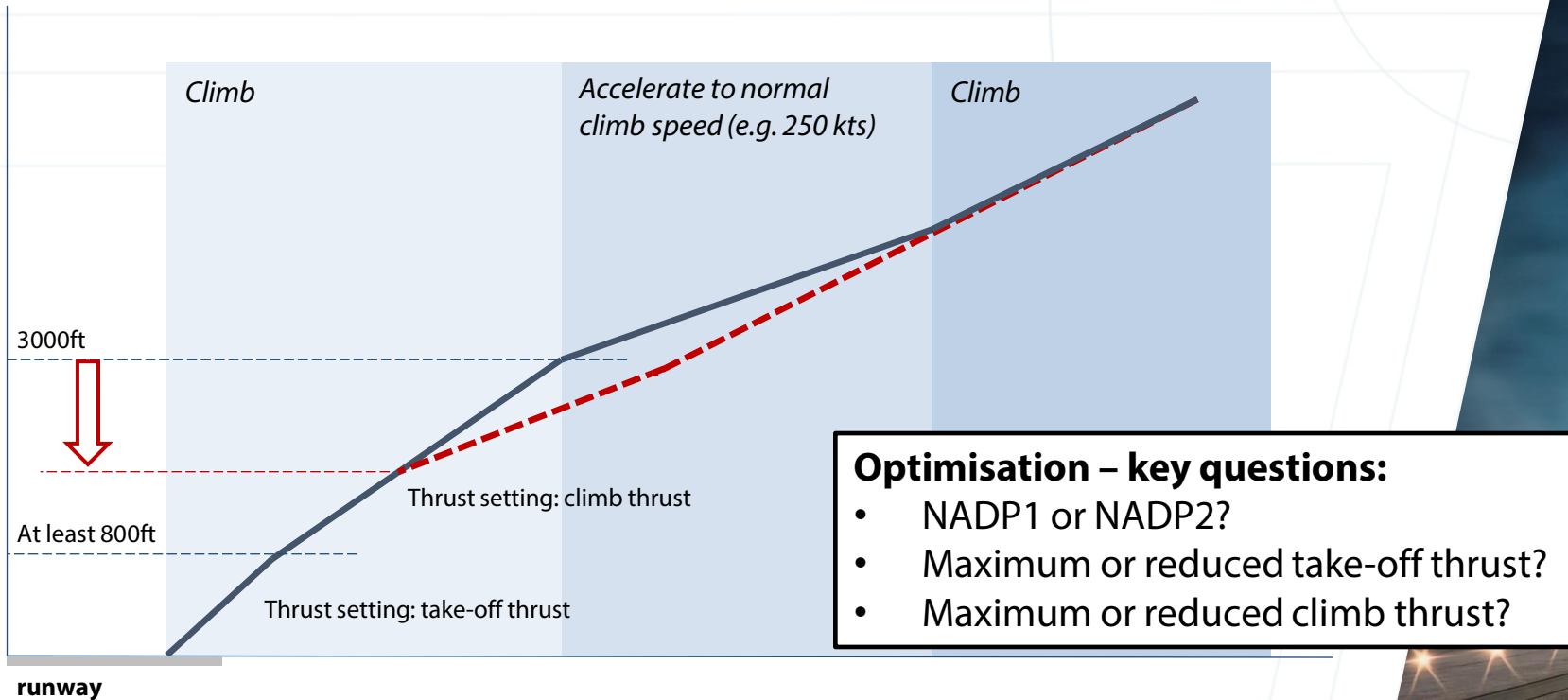
NADP2: start acceleration below 3.000ft





# What is a departure procedure?

NADP2: start acceleration below 3.000ft



## Optimisation – key questions:

- NADP1 or NADP2?
- Maximum or reduced take-off thrust?
- Maximum or reduced climb thrust?



# Some background

## International regulations: ICAO doc8168

- An airline shall develop no more than two noise abatement procedures for each aircraft type
- Two examples: NADP1 and NADP2

## In practice

- NADP1 and NADP2 procedures are standard operating procedures worldwide
- NADP2 is the most standard procedure for noise and fuel optimisation, as most airports are not situated next to dense populations

## London Heathrow

- The AIP does not provide an advised procedure, however Noise Abatement Procedure requires *'Aircraft to be operated in a manner calculated to cause the least disturbance practicable in areas surrounding the airport'*

# Research: explore the environmental impact of different departures

**Selected aircraft:** type A320 (medium size aircraft)

- Most common aircraft at LHR: share 18.5% (see table)
- Along with similar aircraft types: A319, A321, A32N, A32A, A32Q make 55% of aircraft movements

**Different departure profiles have been created**

- NADP1 and NADP2 departures
- For NADP1: a) flaps retraction at 3.000 ft, and b) delayed (at 4.500ft)
- Different thrust settings for take-off thrust (80 – 100%) and climb thrust (70 – 100%)

Noise impact studied for DETLING departures runway 09R.

95% of traffic movements at LHR:

Aircraft type	Share 2019
<b>320</b>	<b>18.50%</b>
<b>319</b>	<b>15.27%</b>
<b>321</b>	<b>7.76%</b>
<b>32N</b>	<b>6.58%</b>
<b>77W</b>	<b>6.55%</b>
<b>789</b>	<b>6.27%</b>
<b>772</b>	<b>5.67%</b>
<b>32A</b>	<b>4.24%</b>
<b>744</b>	<b>3.72%</b>
<b>788</b>	<b>3.60%</b>
<b>388</b>	<b>3.00%</b>
<b>333</b>	<b>2.99%</b>
<b>DH4</b>	<b>2.18%</b>
<b>32Q</b>	<b>1.93%</b>
<b>76W</b>	<b>1.71%</b>
<b>332</b>	<b>1.57%</b>
<b>359</b>	<b>1.11%</b>
<b>73H</b>	<b>1.03%</b>
<b>346</b>	<b>0.74%</b>
<b>CS3</b>	<b>0.69%</b>

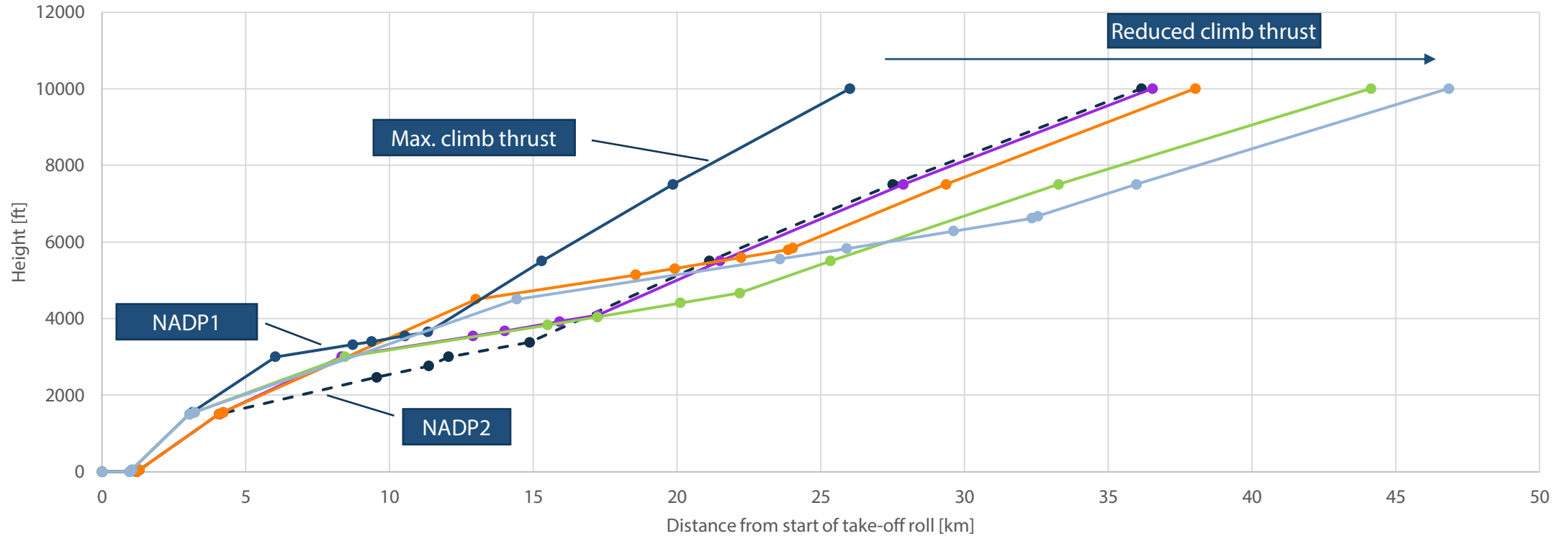
# Research approach

- Reference procedure: NADP2 with reduced take-off and climb thrust
- Selected aircraft type: **A320-211**
- Selected flight distance class: 2 (500 nm – 1000 nm)
- NADP1 acceleration height: a) 3000ft, and b) delayed, at 4500ft
- NADP2 acceleration height: 1500ft
- Noise calculations: INM (~doc29, European standard)
- Noise indicators: Focus on LAmax (loudness) but also SEL (includes the duration of noise event)
- Population 2018: 100x100 grid cells (source: <https://www.worldpop.org/>)



# Airbus A320 – distance class 2, height profiles

A320, distance class 2, selection of studied profiles

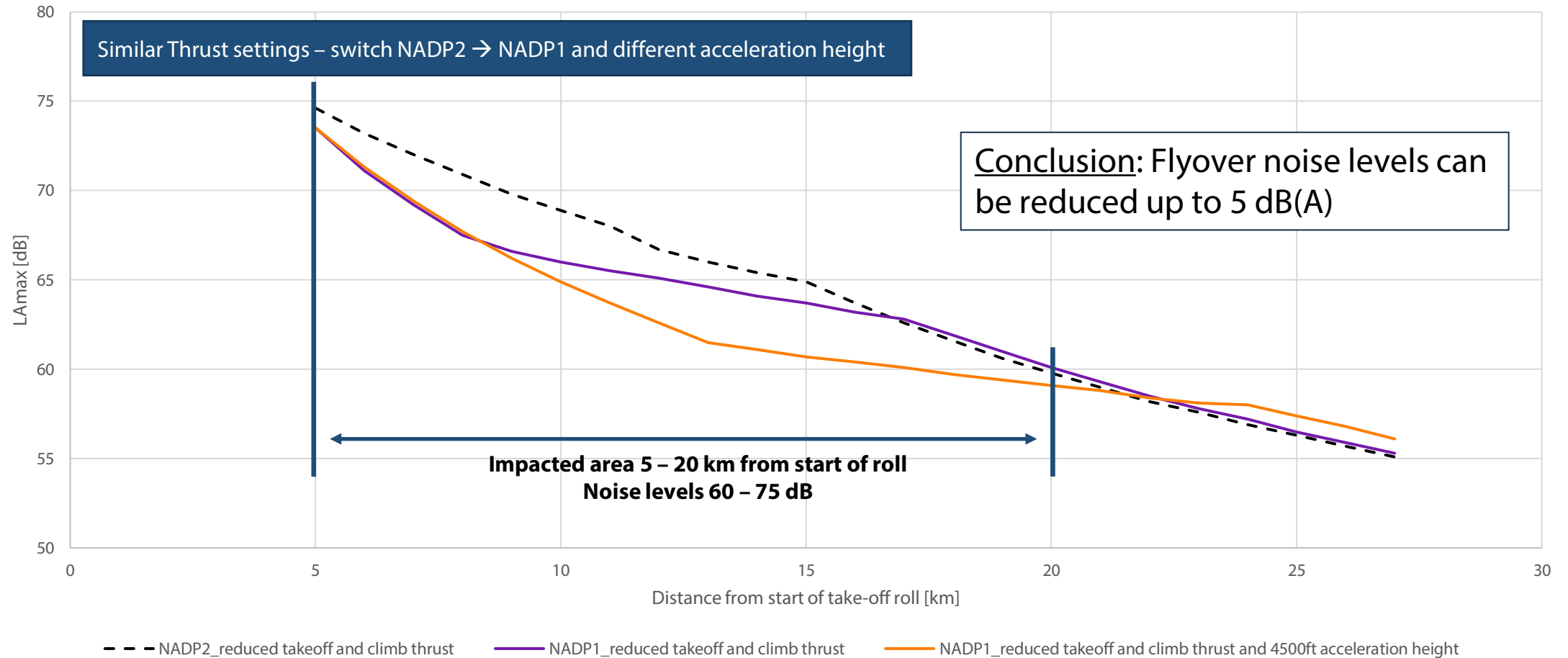


- ● - NADP2\_reduced takeoff and climb thrust
- ● - NADP1\_reduced takeoff and climb thrust
- ● - NADP1\_reduced takeoff and climb thrust and 4500ft acceleration height
- ● - NADP1\_full thrust
- ● - NADP1\_reduced climb thrust (max take-off thrust)
- ● - NADP1\_reduced climb thrust and 4500ft acceleration height (max take-off thrust)



# Airbus A320 – loudness flight path

A320, NADP1, distance class 2 (incl. NADP2)



# Airbus A320 – Affected Population per 5 dB LAmax

Population 2018 (x 1,000):

LAmx	NADP2 reduced thrust (80%)	NADP1 reduced thrust (80%)	NADP1 reduced thrust (80%) start of acceleration at 4.500ft	NADP1 max. thrust	NADP1 max. T/O thrust reduced climb thrust (70%)	NADP1 Max. T/O thrust reduced climb thrust (70%) acceleration at 4.500ft
60 dB	148	147	121	188	127	107
65 dB	66	44	35	82	24	26
70 dB	8.8	2.9	3.0	4.0	3.4	3.4



NADP1



Start acceleration at 4.500ft

Max. thrust

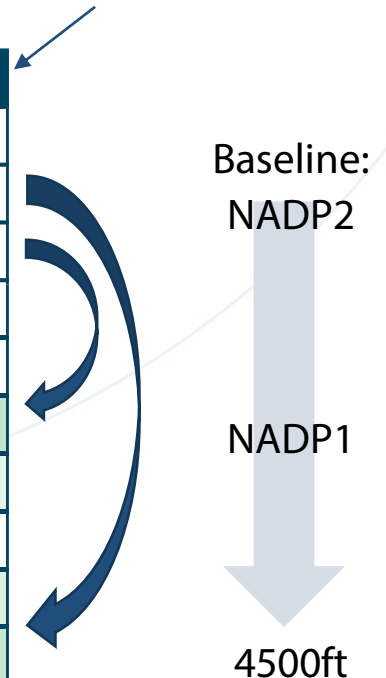
# Airbus A320 – impact of NADP1 and acceleration height

Impact on affected population, per 5 dB

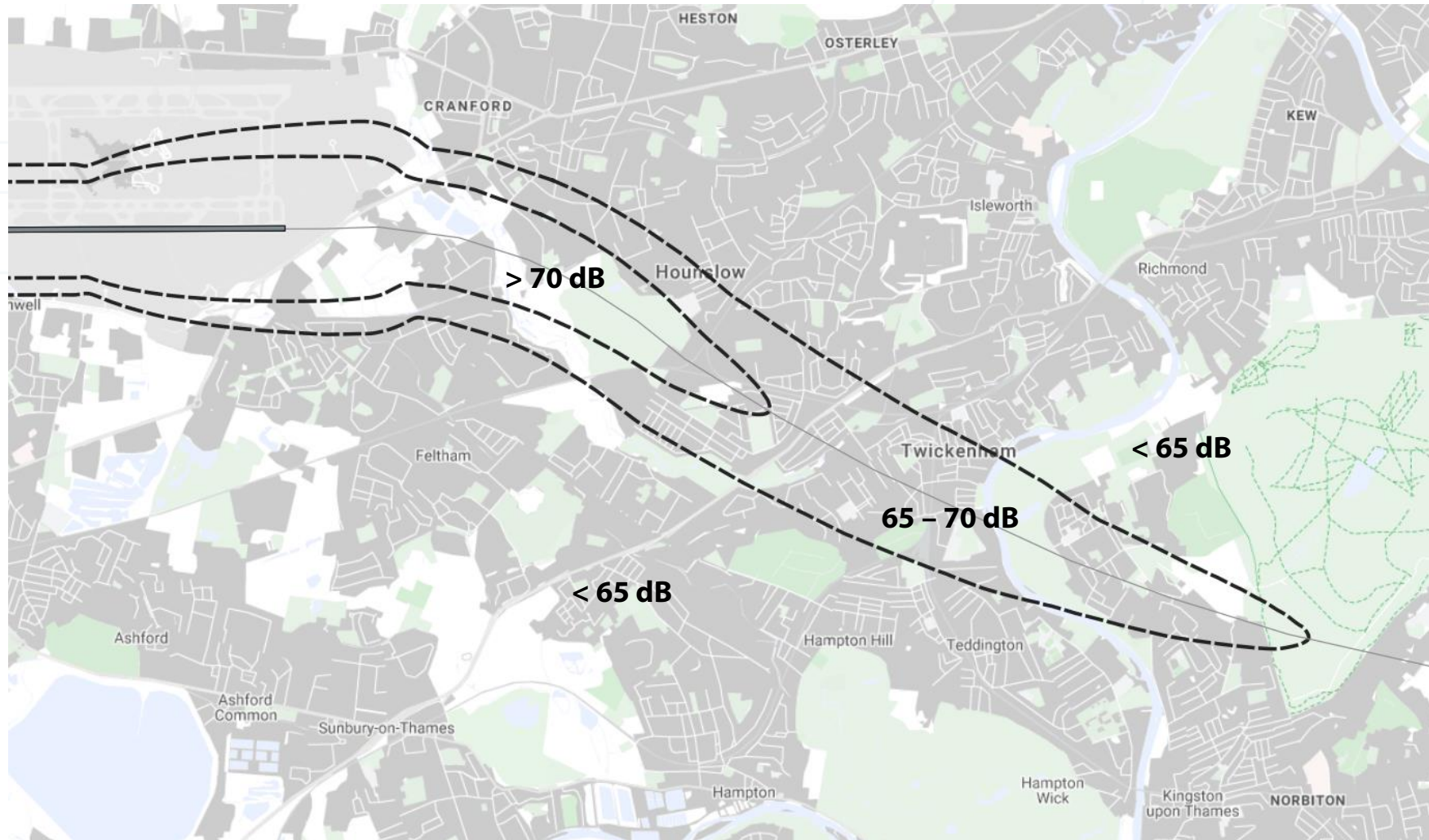
- Reference: NADP2 departure; distance class 2
- Note: cell colored relative to reference

Key - Take-off thrust %\_Climb-Thrust %

	A100%	100%_80%	100%_70%	90%_80%	90%_70%	80%_100%	80%_80%	80%_70%
60 dB	182.4	145.9	131.8	145.1	131.7	181.5	147.5	135.8
65 dB	85.0	64.3	45.2	64.3	44.9	89.0	66.4	47.8
70 dB	15.3	5.1	3.7	6.2	3.0	22.8	8.8	3.0
60 dB	3%	-2%	-3%	-1%	-3%	3%	0%	-2%
65 dB	-3%	-39%	-46%	-37%	-45%	-4%	-34%	-39%
70 dB	-74%	-31%	-8%	-55%	-13%	-79%	-67%	-17%
60 dB	-2%	-17%	-19%	-17%	-20%	0%	-18%	-22%
65 dB	-48%	-55%	-44%	-53%	-41%	-39%	-47%	-36%
70 dB	-73%	-31%	-8%	-55%	-13%	-78%	-66%	-13%



# Airbus A320 – 65 and 70 dB LAmax contours

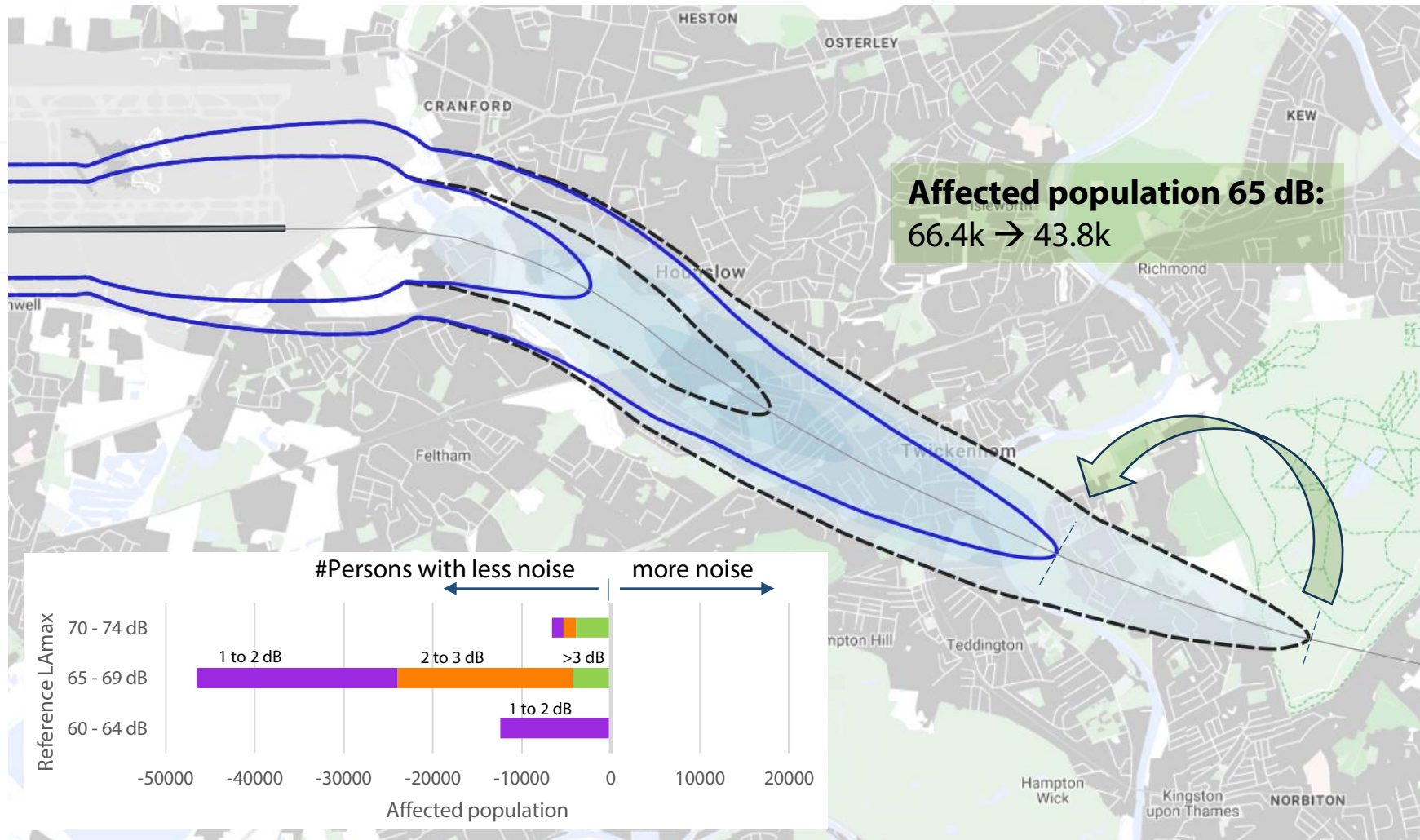


## Reference:

- NADP2
- Reduced take-off thrust
- Reduced climb thrust



# Airbus A320 – 65 and 70 dB LAmax contours



**Reference: NADP2**

- Reduced take-off thrust
- Reduced climb thrust

**NADP1**

- Reduced take-off thrust
- Reduced climb thrust

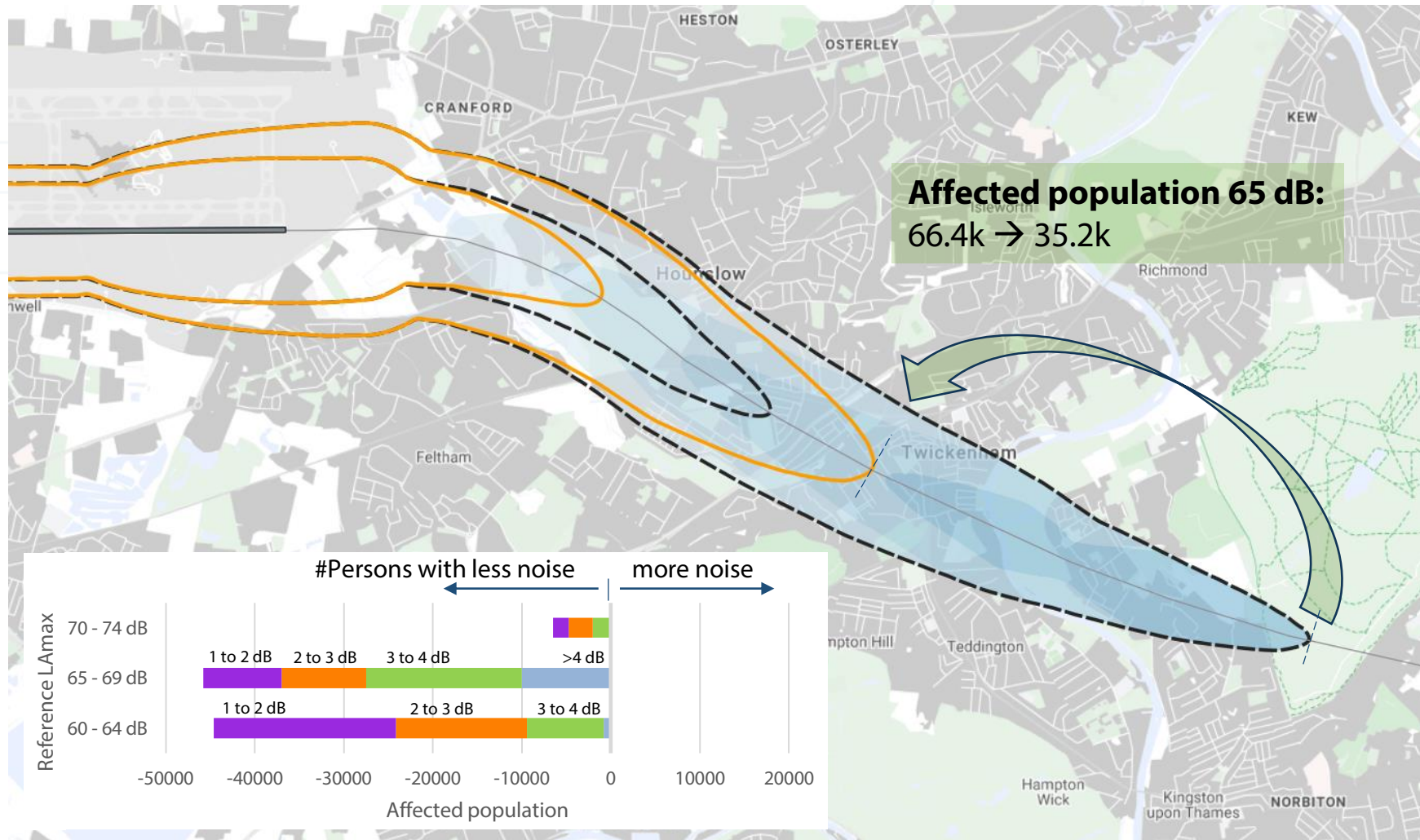
No area sees higher loudness

- noise decrease (>1 dB)
- noise increase (>1 dB)





# Airbus A320 – 65 and 70 dB LAmax contours



Reference: NADP2

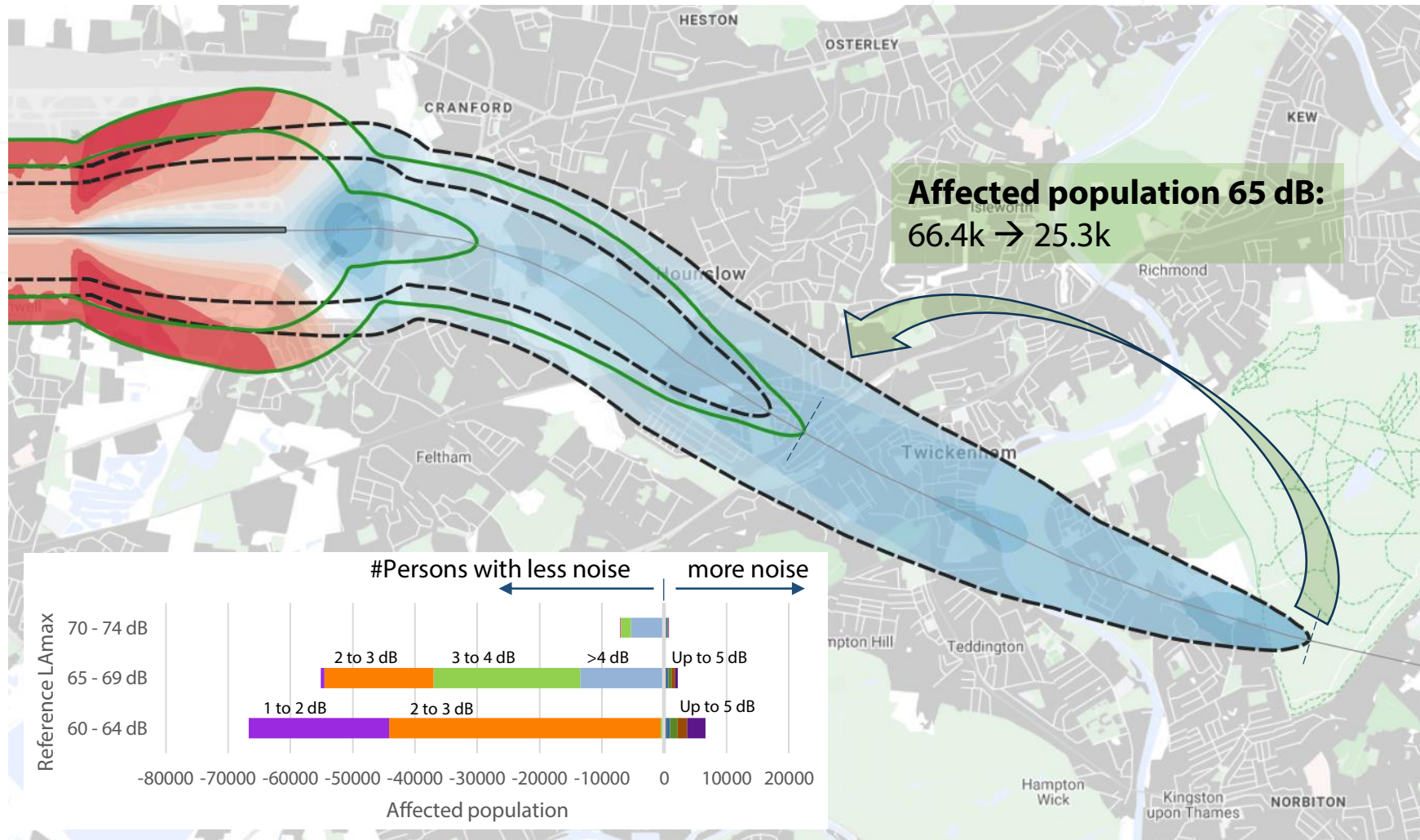
- Reduced take-off thrust
- Reduced climb thrust

NADP1

- Reduced take-off thrust
- Reduced climb thrust
- Acceleration at 4.500ft

No area sees higher loudness

# Airbus A320 – 65 and 70 dB LAmax contours



Reference: NADP2

- Reduced take-off thrust
- Reduced climb thrust

NADP1

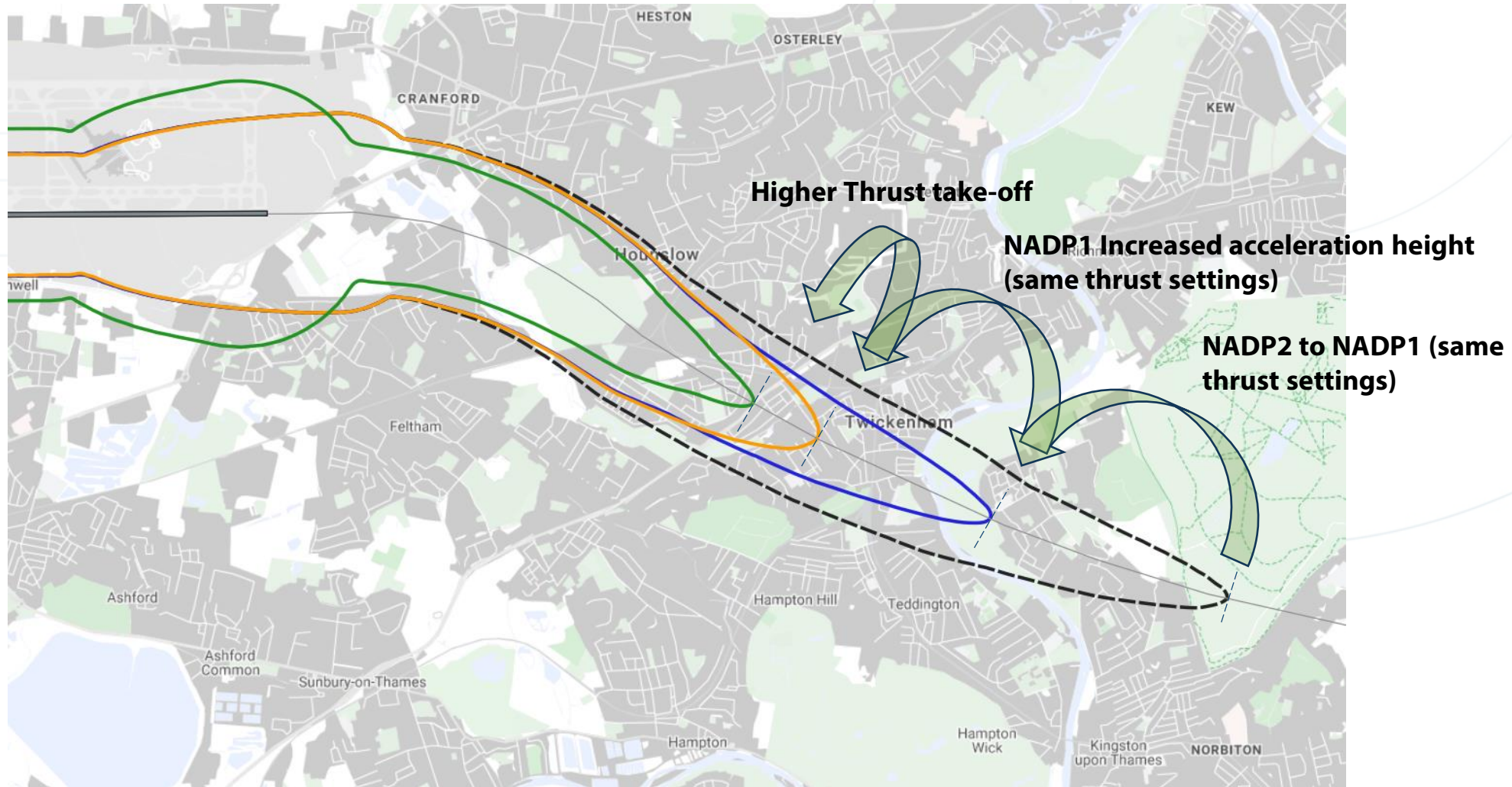
- Max take-off thrust
- Low climb thrust
- Acceleration at 4.500ft

noise decrease (>1 dB)

noise increase (>1 dB)



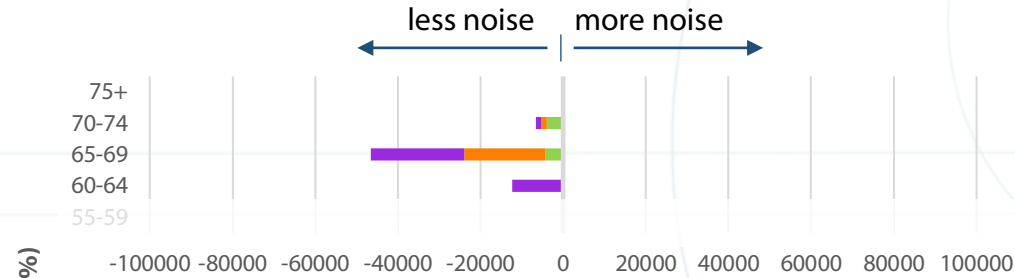
# Airbus A320 – 65 dB LAmax contour



# Airbus 320 Affected population, compared to NADP2 – $LA_{max}$

Focus on daytime noise: 65+ dB(A)  $LA_{max}$

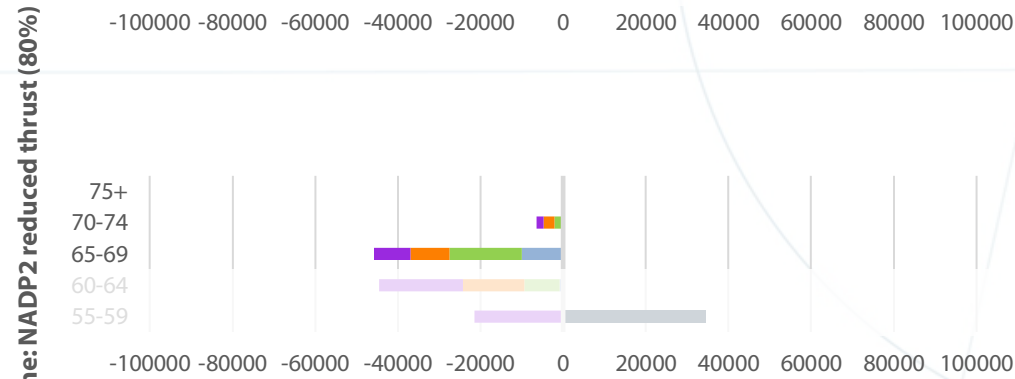
**NADP1**  
80% T/O and climb thrust



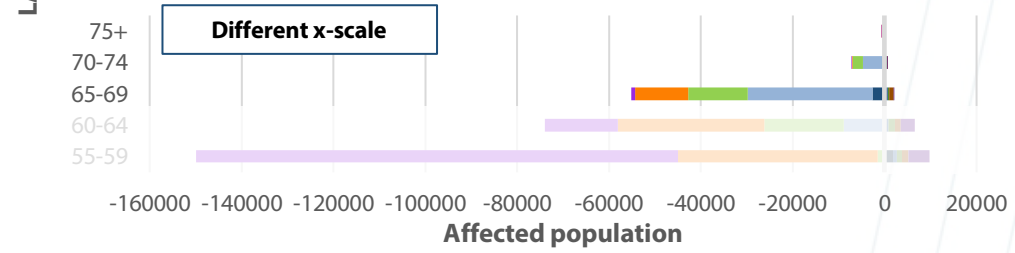
$\Delta LA_{max}$  compared to baseline (NADP2 80%)

- < -5 dB
- -5 to -4 dB
- -4 to -3 dB
- -3 to -2 dB
- -2 to -1 dB
- +1 to +2 dB
- +2 to +3 dB
- +3 to +4 dB
- +4 to +5 dB
- > +5 dB

**NADP1**  
80% T/O and climb thrust  
acceleration at 4.500ft



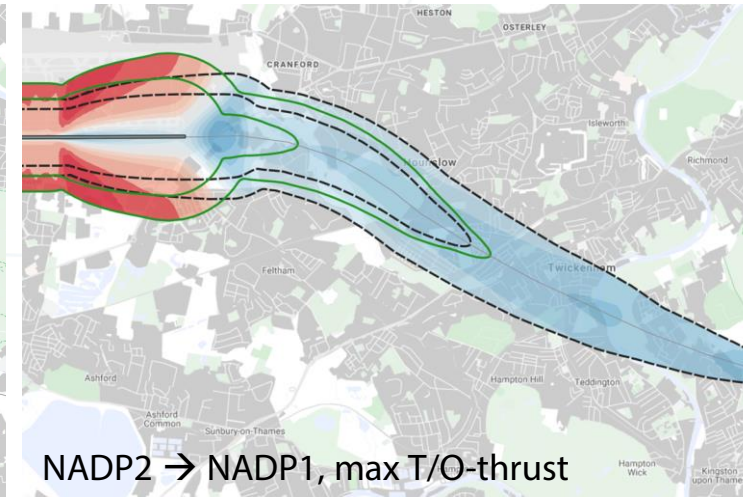
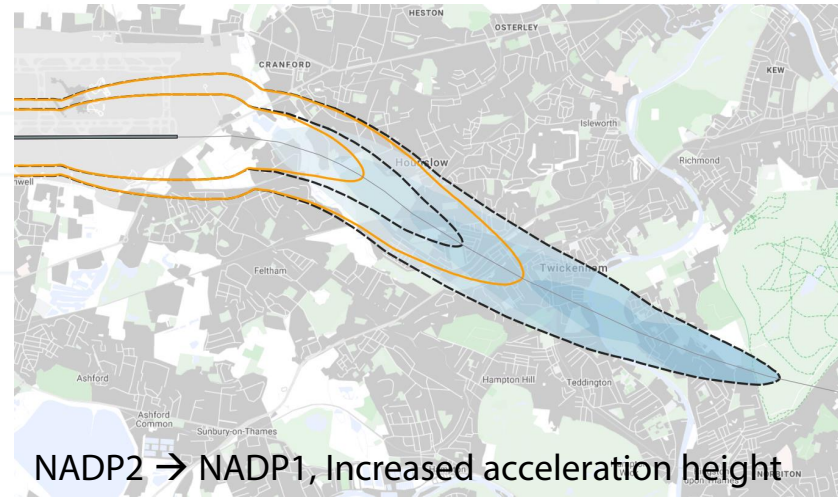
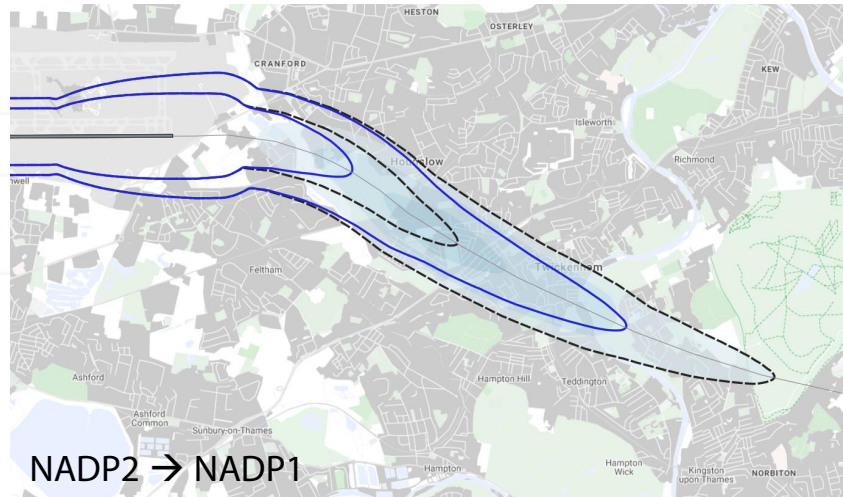
**NADP1;**  
Max. T/O thrust  
reduced climb thrust (70%)  
acceleration at 4.500ft



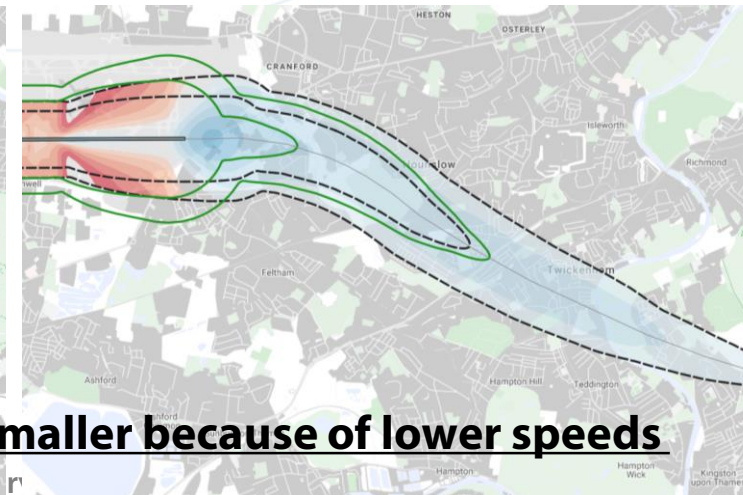
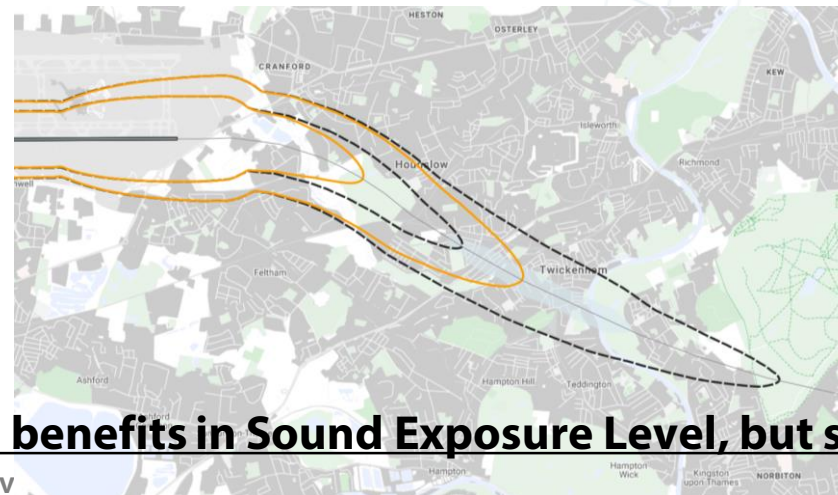
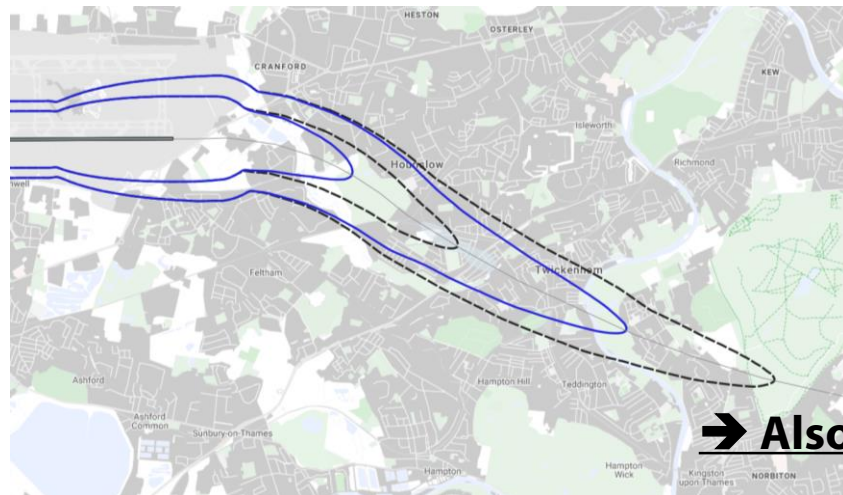


# Airbus 320 Affected population, compared to NADP2 – SEL

## Changes in LA max: loudness



## Changes in SEL (within 65 LAmax area) – includes duration of noise event



➔ Also benefits in Sound Exposure Level, but smaller because of lower speeds

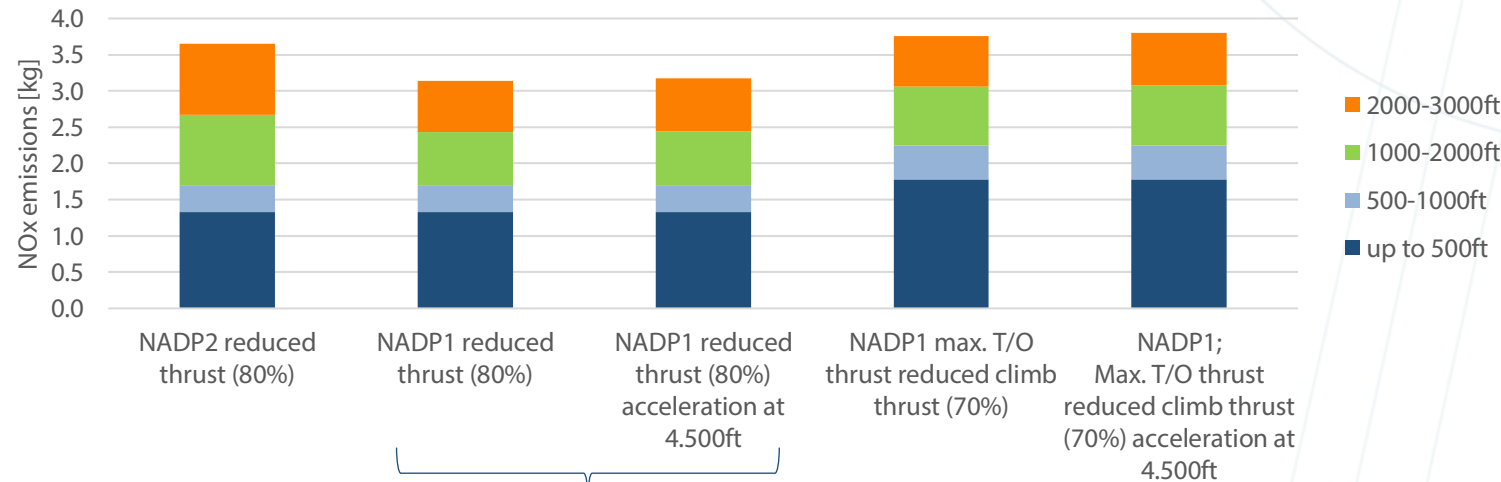
# Fuel burn and NOx

Additional fuel burn and NOx increase per flight with NADP1 and reduced thrust settings.

Fuel burn	NADP2 reduced thrust (80%)	NADP1 reduced thrust (80%)	NADP1 reduced thrust (80%) acceleration at 4.500ft	NADP1 max. T/O thrust reduced climb thrust (70%)	NADP1 max. T/O thrust reduced climb thrust (70%) acceleration at 4.500ft
Additional fuel burn [kg] (% total flight, 4.750 kg)	-	25 (0,5%)	25 (0,5%)	46 (1,0%)	103 (2,2%)
Additional cost of fuel	-	€ 14	€ 14	€ 25	€ 57

Increased thrusts also means increased engine wear

NOx emissions for take-off to 3.000ft



Pollution reduced in mixing zone to 3000ft





# Objective & results

## Objective

Reduce departure noise based on LAmax as much as possible for the largest population (and SELs where possible), while minimising negative effects including increased noise, NO<sub>x</sub> and fuel burn.

## Results

Significant potential to reduce departure noise for A320 aircraft based on both LAmax and SELs for 60+ dB area:

- Change from NADP 2 to NADP 1
- Preferably, increase acceleration height

Further reductions in noise possible by increasing T/O thrust



# Departure noise optimisation

Preliminary results

