NOVA
FLUID MECHANICS

Atlas Business Park
Manchester, UK

Runway Wind Impact Study

Appendix C

2nd March 2026



APPENDIX C. AIRBOURNE WEATHER RADAR

Following review of NOVA's initial report, it is understood that the Aerodrome Safeguarding Team have raised concerns about the potential impact of the proposed development on "airborne weather radar". Specifically, whether the number of automatic "go-around" instructions will increase due to detection of windshear events caused by the building induced turbulent effects (the "wake").

C.1. Assessment Methodology

Based on the ICAO Manual on Low-level Wind Shear (Doc 9817)[1], it is understood that airborne weather radar systems determine the severity of wind shear based on the so-called F-Factor.

The F-Factor[2] is defined as:

$$F = \frac{\dot{U}_x}{g} - \frac{w}{V_a}$$

Where $\dot{U}_x$ is the Lagrangian derivative of the horizontal component of wind along the flight path (positive for a tailwind), w is the vertical component of the wind, V_a is the airspeed, and g is the gravitational acceleration.

Furthermore, it is understood from ICAO Doc 9817 that due to the dependence of the F-Factor on airspeed, the certification of airborne wind shear warning systems is based on assumed airspeeds of 120, 150 and 200 knots, which are selected to be representative of typical airspeeds for landing and take-off.

The calculation of $\dot{U}_x$ is dependent on the aircrafts position, and can readily be assessed for reactive type systems. However, in order to extend this parameter to predictive systems, the Lagrangian derivative is estimated based on a "frozen wind field" hypothesis[2]:

$$\dot{U}_x = \frac{\delta U_x}{\delta x} V_a$$

This approach can also be adopted to estimate the F-Factor associated with the wind tunnel measurements.

Finally, ICAO Doc 9817 also references the work of Procter et al[3], who state that:

> "*The Federal Aviation Administration (FAA) has adopted the 1-km average F-factor as its hazard metric for windshear detection systems on jet transports, and considers windshear hazardous for F > 0.1, and a must alert threshold at 0.13*"

This defines the applicable threshold for the assessment of the F-Factor. Whilst the wind tunnel measurements only extend over 400 m, meaning an average over 1 km is not possible, Lewis et al[4] indicate that over a shorter distance, a higher averaged F-Factor is required to give the necessary energy loss. Therefore, applying the 0.1 threshold associated with a 1 km average to the 400 m average from the wind tunnel data is expected to be conservative.

Consequently, in order to provide guidance on the impact of the proposed development on airborne weather radar during landing, and thus the potential for an increase in automatic "go-around" instructions, the associated F-Factor will be calculated using the following procedure:

1. Calculate the normalised F-Factor for each measurement location, for each wind direction, based on the assumption of a "frozen wind field", for airspeeds of 120, 150 and 200 knots;

2. Determine the mean wind speed at reference height, for each wind direction, that is required to exceed the averaged F-Factor threshold of 0.1 along each of the of 3° (5.24%) landing trajectories assessed in the wind tunnel, spanning the runway threshold and far touchdown markings; and
3. Determine the annual exceedance of the resulting wind speeds, using appropriate wind statistics for the airport.

By comparing the annual exceedance for the existing site with that for the proposed development, the impact of the proposed development on airborne weather radar can be quantified.

C.2. Results Summary

The resulting impact on airborne weather radar along the flight path, derived from the assessment of the F-Factor, is summarised as follows:

- The change in the annual probability of exceedance of the averaged F-Factor threshold is presented in Tables C.1 to C.3, for airspeeds of 120, 150 and 200 knots, respectively.

C.3. Discussion

The maximum change in the annual probability of exceedance of the averaged F-Factor threshold (see Tables C.1 to C.3) is ±0.0%. This indicates that there will be no discernible increase in the occurrence of automatic “go-around” instructions as a consequence of the proposed development.

In practical terms, this can be demonstrated by calculating the F-Factor associated with a specific scenario. For example, based on an airspeed of 150 knots and a 50-yr return period wind speed (typical of the level applied to building design and equivalent to an annual probability of exceedance of 2.0%) blowing from 315° (being the wind direction for which the development would be expected to have the highest impact) the worst case averaged F-Factor associated with the existing scenario is 0.02, which under the same conditions for the proposed development would remain at 0.02. In either case, a windshear warning would not be triggered. A similar result can be demonstrated for all of the wind directions assessed.

Consequently, in our professional opinion, the proposed development should not contribute to any significant increase in wind shear events, which reinforces the conclusion of the wind tunnel studies, namely that the proposed development will have no practical impact on operations along the flight path for Runway 05L/23R of Manchester Airport.

References

[1] ICAO Manual on Low-level Wind Shear, Doc 9817 AN/449, First Edition, 2005.

[2] Bowles, 1990. Reducing wind shear risk through airborne systems technology, 17th Congress of the ICAS, Stockholm, Sweden. ICAS-90-1.9.3.

[3] Procter, Hinton & Bowles, 2000. A wind shear hazard index, Preprints of 9th Conference on Aviation, Range, and Aerospace Meteorology, Orlando, FL.

[4] Lewis, Robinson, Hinton and Bowles, 1994: The relationship of an integral wind shear hazard to aircraft performance limitations, NASA TM — 109080.

Table C.1: Annual probability of exceedance of F-Factor threshold during landing, 120 knots airspeed

Wind Direction	Exceedance of F-Factor Threshold (F=0.10)		Absolute Difference
	Existing Site	Proposed	
0.0°	0.0%	0.0%	0.0%
22.5°	0.0%	0.0%	0.0%
45.0°	0.0%	0.0%	0.0%
67.5°	0.0%	0.0%	0.0%
90.0°	0.0%	0.0%	0.0%
112.5°	0.0%	0.0%	0.0%
135.0°	0.0%	0.0%	0.0%
157.5°	0.0%	0.0%	0.0%
180.0°	0.0%	0.0%	0.0%
202.5°	0.0%	0.0%	0.0%
225.0°	0.0%	0.0%	0.0%
247.5°	0.0%	0.0%	0.0%
270.0°	0.0%	0.0%	0.0%
292.5°	0.0%	0.0%	0.0%
315.0°	0.0%	0.0%	0.0%
337.5°	0.0%	0.0%	0.0%

Table C.2: Annual probability of exceedance of F-Factor threshold during landing, 150 knots airspeed

Wind Direction	Exceedance of F-Factor Threshold (F=0.10)		Absolute Difference
	Existing Site	Proposed	
0.0°	0.0%	0.0%	0.0%
22.5°	0.0%	0.0%	0.0%
45.0°	0.0%	0.0%	0.0%
67.5°	0.0%	0.0%	0.0%
90.0°	0.0%	0.0%	0.0%
112.5°	0.0%	0.0%	0.0%
135.0°	0.0%	0.0%	0.0%
157.5°	0.0%	0.0%	0.0%
180.0°	0.0%	0.0%	0.0%
202.5°	0.2%	0.2%	0.0%
225.0°	0.0%	0.0%	0.0%
247.5°	0.0%	0.0%	0.0%
270.0°	0.0%	0.0%	0.0%
292.5°	0.0%	0.0%	0.0%
315.0°	0.0%	0.0%	0.0%
337.5°	0.0%	0.0%	0.0%

Table C.3: Annual probability of exceedance of F-Factor threshold during landing, 200 knots airspeed

Wind Direction	Exceedance of F-Factor Threshold (F=0.10)		Absolute Difference
	Existing Site	Proposed	
0.0°	0.0%	0.0%	0.0%
22.5°	0.0%	0.0%	0.0%
45.0°	0.0%	0.0%	0.0%
67.5°	0.0%	0.0%	0.0%
90.0°	0.0%	0.0%	0.0%
112.5°	0.0%	0.0%	0.0%
135.0°	0.0%	0.0%	0.0%
157.5°	0.0%	0.0%	0.0%
180.0°	0.0%	0.0%	0.0%
202.5°	0.9%	0.9%	0.0%
225.0°	0.0%	0.0%	0.0%
247.5°	0.0%	0.0%	0.0%
270.0°	0.0%	0.0%	0.0%
292.5°	0.0%	0.0%	0.0%
315.0°	0.0%	0.0%	0.0%
337.5°	0.0%	0.0%	0.0%