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04 February 2016

Peter Cromarty
Executive Manager Airspace and Aerodrome Regulation
Civil Aviation Safety Authority
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Email: airlineops@casa.gov.au

Our Ref: T40-00-86

Dear Peter,

AusALPA RECOMMENDATION IN REGARD TO THE DRAFT MAJOR DEVELOPMENT PLAN FOR 9 MOLONGLO DRIVE, CANBERRA AIRPORT

The Australian Airline Pilots' Association (AusALPA) represents more than 5,000 professional pilots within Australia on safety and technical matters. We are the Member Association for Australia and a key member of the International Federation of Airline Pilot Associations (IFALPA) which represents over 100,000 pilots in 100 countries. Our membership places a very strong expectation of rational, risk and evidence-based safety behaviour on our government agencies and processes.

AusALPA is concerned that the current standard that underpins the assessment of airport developments for building-induced turbulence is inadequate. In our view, the requirements of the National Airports Safeguarding Framework Guideline "B" (NASFG "B") are seriously deficient and the wind tunnel modelling conducted to meet that guideline is unlikely to detect the full extent of any building-induced turbulence in the real world operational context.

We have closely examined the wind assessment conducted in support of the draft MDP for 9 Molonglo Drive, Canberra Airport and we have sought an independent review of that assessment by a well-known wind engineering consultancy, MEL Consultants Pty Ltd. That review reinforced our concerns about the effectiveness of the assessment to achieve the intended purpose of NASFG "B". The letter from MEL Consultants is enclosed for your information.

We have also enclosed an AusALPA Position Paper setting out what we believe is required to properly manage the risk to safe flight operations at Australian airports. The paper is framed in the context of the draft MDP for 9 Molonglo Drive to illustrate our case.

AusALPA recognises that the necessary amendments to NASFG "B" will require appropriate consultation before the necessary changes can be affected. We also recognise that because the NASF comes under the auspices of the Standing Council on Transport and Infrastructure (SCOTI) that agreement between the States and the Commonwealth may not be as rapid as the problem deserves. Nonetheless, the risk cannot be ignored simply because the guidance is presently lacking.

The quality, scale and scope of wind engineering assessments for building-induced turbulence for all airports demands urgent action. Canberra Airport already has a problem with building-induced turbulence at the threshold of runway 12 and in the touchdown zone on runway 35 as a result of what most pilots regard as inappropriate development and CASA must ensure that the situation is not exacerbated further by buildings that adversely affect the operational airspace.

AusALPA does not accept that the draft MDP before the Minister is based on a valid assessment of the turbulent wake of the proposed development.

We have no doubt that the turbulent wake will have consequences – what is not known is the extent of those consequences, the associated risk and what may be necessary in terms of mitigation. When a proper investigation has been completed, AusALPA believes that the risk management process must be an open and transparent process to which we are a party.

We are disappointed that the safety concerns that we have raised have not previously surfaced as a result of the various aircraft operators' considered inputs to the NASF. AusALPA would like to reassure you that we stand by our long standing commitment to assist CASA and any related parties as best as we are able.

Yours sincerely,

David Booth
President AusALPA
President AFAP

Nathan Safe
President AIPA

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Enclosures:

A. MEL Consultants Pty Ltd, *Canberra Airport: 9 Mongolo Drive - Review of Windtech environmental wind report*, 21 December 2015

B. AusALPA Position Paper *Managing the Risk of Building Generated Windshear and Turbulence at Airports,* 28 January 2016

Enclosure A

MEL CONSULTANTS PTY LTD

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21 December 2015

Dick MacKerras
Technical, Safety and Regulatory Affairs Advisor
Australian and International Pilots Association (AIPA)
Suite 6.01, Level 6, 243-249 Coward St
Mascot NSW 2020

Dear Dick,

Canberra Airport : 9 Mongolo Drive
Review of Windtech environmental wind report

We have reviewed the wind effects report by Windtech (document number WC232-04F02, Rev0, dated 22 September, 2015) for the assessment of wind shear from the 9 Mongolo Drive development. The report has used the NASAG guidelines as a measure of the building generated wind shear. Turbulence intensity levels were also measured in an effort to assess the local flow disturbance of the building. The Mean Wind Deficit was measured in accordance with these guidelines. We provide specific comments on the assessment with regards to the following key issues:

Flow Physics Affecting Aircraft Operations

The NASAG guidelines, and consequently the conclusions of the report, fail to address the key flow physics that affect aircraft operations. The concept of turbulence is used in a general sense with no reference to the specific qualities of the turbulence that would be expected to affect aircraft dynamics. Turbulence is comprised of a range of scales (temporal and spatial) ranging from the macro (which are the ones of interest here and have the potential to affect aircraft operations) to the micro, which affect the local, small scale boundary layer flows over the aircraft surfaces. As such any study of the impact of building wakes upon aircraft operations need to be clear on what aspect of the turbulence is being considered. In the present instance the intensity as well as the scale (spatial and temporal) of the turbulence needs to be quantified, the latter of which is critical for assessing the wake turbulence impact on aircraft of various sizes. This approach has been demonstrated in Melbourne and Kostas, 2013, where it was shown that the timescales of flow events, velocity gradients and the size of flow structures are important but is absent in the Windtech report. Any criteria based on 1min or 10 min mean wind speeds would be hopelessly inadequate and would completely miss the physics of how wind gusts effect aircraft as shown in our recent paper. The gust wind speeds that are important are those lasting in the order of 10 seconds at the most. These are the gust shear flows of the order of the aircraft size or more significantly three to five times the wing chord length. These are the length and time scales that are important as they generate the sudden changes in wing lift that cause pitch-up and roll.

Flow Diagnostics and Wind Tunnel Testing

With reference to the previous discussion the measurement and characterisation of the turbulence scales requires more detailed flow measurements and analysis than is currently presented in the Windtech report. It appears that measurements (23 in total) along the runway were conducted at the development building height using a single component hot-wire probe. A detailed study characterising the length and time scales of wake turbulence would require measurements within a three dimensional volume in the wake of the development that would allow quantification of spatial gradients of the turbulence along the flight path for various wind directions. The volume of measurement should be sufficient to cover a range of thresholds to account for variations in approach, aircraft size and type and well as future runway modifications. Furthermore, to be able to measure spatial and temporal gradients, simultaneous measurements from multiple probes would be necessary as well as the simultaneous measurement of the three components of velocity. Ideally the characterisation of the building induced wake turbulence is well suited to current flow field measurement techniques capable of measuring simultaneous three components of velocity over two dimensional areas of flow.

Site Specific Wind Data and Design Events

The choice of appropriate wind data and selection of design events, although important, can be considered as a separate exercise from the wind tunnel testing programme. Measurements in the wind tunnel can be made over a range of wind speeds and can, at a later time, be post-processed and scaled to any arbitrary criterion. It has been noted by others, and MEL Consultants concurs, that the immediate requirement is to establish whether there is an adverse wind scenario for 9 Mongolo Drive. The frequency of occurrence of that scenario could then be determined through analysis of site specific wind data at a later time.

Yours sincerely,

Dr. J. Kostas
MEL Consultants Pty Ltd

Professor W.H. Melbourne
MEL Consultants Pty Ltd

References

Melbourne, W.H. and Kostas, J., "Embedded Turbulence in the Wake of Buildings Affecting Aircraft Operations", Proceedings of the 16th Australasian Wind Engineering Society Workshop, Brisbane, Australia, 18-19 July, 2013.

Enclosure B

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AusALPA POSITION PAPER

MANAGING THE RISK OF BUILDING GENERATED WINDSHEAR AND TURBULENCE AT AIRPORTS

(WITH PARTICULAR REFERENCE TO THE DRAFT MAJOR DEVELOPMENT PLAN FOR 9 MOLONGLO DRIVE, CANBERRA AIRPORT)

The Australian Airline Pilots' Association (AusALPA) represents more than 5,000 professional pilots within Australia on safety and technical matters. We are the Member Association for Australia and a key member of the International Federation of Airline Pilot Associations (IFALPA) which represents over 100,000 pilots in 100 countries. IFALPA holds permanent observer status at ICAO and participates at all levels in its activities including panels and committees. Both IFALPA and AusALPA aim to actively pursue safety, risk and technical outcomes that enhance civil aviation worldwide.

Accordingly, this Position Paper sets out the views and recommendations of AusALPA in regard to managing the risk of building generated windshear and turbulence at Australian airports. Our position is consistent with IFALPA policy which seeks formal amendment of Chapter 4 of ICAO Annex 14[1] to require scientific assessment of the environmental consequences of building developments in the vicinity of operational flight paths.

To ensure a practical basis for our position, the paper is framed around the wind assessment[2] and the land use planning framework relevant to the draft Major Development Plan (MDP) for 9 Molonglo Drive, Canberra Airport which is currently before the Minister for Infrastructure and Regional Development for approval in accordance with s94 of the *Airports Act 1996.* While development controls within the *Airports Act 1996* apply only to Commonwealth airports, it is our view that the principles should apply to all Australian airports and the relevant land use planning jurisdictions.

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1 International Civil Aviation Organisation (ICAO) 2013, Annex 14 to the Convention on International Civil Aviation, *Aerodromes*, Volume I Aerodrome Design and Operations, 6th Edition, Montreal

2 Unfortunately, this document is not publicly available, nor is it required to be. However, sufficient descriptive reference will be provided for those who do not have official access. The Preliminary Draft MDP dated April 2015 provided for public comment stated at page 24 "…the wind speed deficit criteria limit of 7 knots is not reached for Runway 17/35."

The Hazard

Ever since we abandoned "all-over airfields", built substantial runways and then filled in the flat grassy surrounds with buildings, aircraft have had to operate in often-difficult turbulence environments that can be attributed to, or exacerbated by, those buildings.

When buildings and structures interfere with the normal passage of the wind, they create turbulent wakes containing energetic and complex time-dependent flows and shears with generally finite lives and volumes of influence that may impact an aircraft penetrating the flow at constantly changing angles. If the aircraft size is close to that of the turbulent wake, different energy levels will be encountered across the aircraft. Aerodynamically, an aircraft responds to both the angle of impact and the energy of the flow. A sudden change of either or both factors will affect both the flyability and the controllability of the aircraft and, if large enough, may lead to an accident.

Controlling the Hazard

Given that we cannot control the energy source for building-induced turbulence, the wind, we can only control the trigger mechanism, the building.

Controlling building development for turbulence effects on aircraft operations in Australian jurisdictions is complex, not only because many buildings invoke unique aerodynamic responses to wind but also because each development location may invoke jurisdictional issues for land use control in addition to the more obvious issue of proximity to runways.

Until very recently, we failed to safeguard our airports with proper land-use planning controls to ensure that development does not interfere with their primary purpose of permitting the safe operation of aircraft. There is something of a history of Commonwealth versus State discord over inconsistent land use controls and the intense commercial developments at Commonwealth airports has long been a topic of concern. In particular, Canberra airport is already known within the pilot community as a difficult environment for landing and go around due to building-induced turbulence from what we consider to be some inappropriate developments.

We acknowledge that urban encroachment around airports is a fact of life, as is on-airport development. AusALPA is comfortable with the 'airport city' concept, but only if the flight safety risks that flow on from building developments are correctly recognised, classified and then, if problematic, satisfactorily mitigated or removed.

While the daily consequences of historical failure to properly safeguard aerodromes can be seen elsewhere at places like Heathrow and Narita, AusALPA recognises the significant progress made in land-use planning through the National Airports Safeguarding Framework (NASF) and the related Guidelines, especially NASF Guideline "B" (NASFG "B") *Managing the Risk of Building Generated Windshear and Turbulence at Airports*. However, those guidelines are prospective, technically voluntary and apply only where the controlling jurisdiction has adopted them within their own planning controls.

THE PROBLEM

AusALPA has formed the view that many of the wind engineering assessments currently being conducted in Australia for the purposes of identifying the risk of building-induced windshear and turbulence at airports are inadequately focused, largely incomplete and potentially misleading.

We are particularly concerned that, as such, they often create an unjustified aura of safety comfort within Government and among developers, aircraft operators and the general public, despite being incomplete investigations which use limited processes to measure only some of the safety threshold criteria recommended by one of the premier international aviation research laboratories.

> **NOTE:** In coming to this conclusion, AusALPA in no way wishes to impugn the intentions of those involved, but rather to highlight what we see as a lack of operational understanding of the application and, importantly, limitations of the available science and research specific to building-induced windshear and turbulence at airports.

The Operational Issues

Although helicopters are similarly at risk, for simplicity we will limit the discussion to aeroplanes used in commercial operations.

The lead agency for research specifically targeted at building-induced turbulence is accepted as NLR, the National Aerospace Laboratory of the Netherlands. This status is a reflection of their work over the last 20 years associated with operational issues at Amsterdam Airport Schiphol ("Schiphol") caused by urban encroachment, on-airport development and a naturally severe wind environment. The primary reference in the context of this paper is their report NLR-TP-2010-312 *Wind criteria due to obstacles at and around airports,* released in July 2010[3].

Among many of the issues explored in that research, the primary area of concern for building-induced turbulence was the airspace between the surface and 200 feet[4] (61m). For the most part, existing airspace controls mitigate the wind effects of large structures at greater heights.

Aircraft operations at airports within the airspace between the surface and 200 feet include take-offs, landings and go-arounds. Take-offs are increasing energy situations with stabilised high thrust settings that are generally affected far less during their brief exposure time than landings and go-arounds and are not considered further. Landings are high drag, lower power and decreasing energy situations that are particularly vulnerable and attract the greatest concern. However, while excluded from the NLR study for scope limitation, go-arounds are also vulnerable as they involve transitioning from the high drag, lower power and decreasing energy landing situation to a lower drag, increasing power and energy situation similar to a take-off. During that transition, significant handling errors can exacerbate the vulnerability of the aircraft to the adverse effects of turbulence. Importantly, go-arounds can occur at any part of the 200ft window, including from on the runway, but will not necessarily track the runway centreline.

Importantly, there can be no presumption that flight path management will be automatic and highly accurate – we must cater for various system failures as well as aircraft that lack the inherent capabilities or the latest equipment and human capabilities in manual

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[3] This report superseded NLR-CR-2006-261 of the same title published in May 2008 and is essentially identical in content. NLR-TP-2010-312 was available when the NASF Guidance Material (see reference at footnote 4) was compiled for the then Department of Infrastructure and Transport and published in December 2012.

[4] Feet remain as the aeronautical measure of height and altitude for aviation operations in most parts of the world. Metres are the measure of length for ground-based measurements other than for navigation, where the measure remains as the nautical mile (1 nm = 6080ft = 1852m).

flight in difficult conditions. AusALPA asserts that these presumptions are probably the greatest source of inadequate investigation of building-induced turbulence in Australia.

The Economic Issue

Building-induced turbulence of such magnitude as to affect safe aircraft operations is avoidable. AusALPA stresses that the safety consequences of inappropriate developments will largely persist for the life of the building. Every time an approach and landing is abandoned or in prolonged adverse weather situations where an aircraft diverts to another airport or a flight is cancelled prior to departure, there are significant costs involved, both direct and indirect.

In our view, there is effectively a market failure in that the developer, most often the airport operator, does not bear those costs. We believe that the majority of the economic penalty for go arounds and diversions for unsuitable landing conditions are borne by the travelling public foremost and the broader economy generally through opportunity costs and the loss of transport efficiency. AusALPA suggests that this lack of “downside” for the development proponent justifies careful and independent scrutiny of supplied data.

The Airport Planning Issue

AusALPA’s long term strategy is to widen the requirement for proper assessment of proposed developments for building-induced turbulence to all airports of an appropriate size used for public transport in Australia, regardless of land use jurisdiction. However, even under the current arrangements, each proposed development must be examined not only in the context of the existing runway infrastructure but also in terms of future runway plans.

The draft MDP for 9 Molonglo Drive illustrates this issue well. Attachment 1 shows the location of the proposed building relative to the existing threshold for Runway (RW) 35 as well as the potential future threshold, being approximately abeam the midpoint between the two. In the westerly and north-westerly winds that predominate when RW 35 is in use, the turbulent wake of the proposed building will affect the approach surfaces of the existing runway configuration but not the runway itself. However, if the building is constructed and the runway is subsequently extended, those same winds will cause the turbulent wake to directly impinge the runway touchdown zone as well as the runway approach surfaces.

Even though s89(1)(b) of the *Airports Act 1996* would require an MDP for the runway extension, that development itself would not normally trigger a building-induced turbulence assessment and, in any event, the building would already exist and post-construction mitigation may well be impractical.

AusALPA recommends that the NASF should explicitly consider a closed loop process that ensures that building-induced turbulence assessments from existing structures are part of the decision-making for runway and related infrastructure developments.

TECHNICAL CONSIDERATIONS

The Science

Turbulence remains as one of the truly unresolved phenomena in the physical world. Its very unpredictability means that turbulence models are generalisations, particularly for our immediate focus on turbulence in the earth’s boundary layer. Despite the attention given to the assessment of building-induced turbulence in Schiphol and Hong

Kong, most of the underpinning research has arisen from the historical applications of architectural and air quality outcomes rather than from any consideration of aerodynamically responsive bodies such as aircraft.

Wind, the movement of air within the atmosphere, is characterised by a general flow created by long period synoptic mechanisms overlaid by a more localised level of turbulence created by shears as various parcels of air move over each other and across the Earth's surface. As we have identified, the interference of a normal wind flow caused by one or more buildings creates a turbulent wake that can adversely affect aircraft. Because that wake is superimposed on the localised synoptic turbulence, there will be areas where the two flows are additive and areas where they cancel each other out, thus amplifying the natural level of variability of the wind strength and direction.

It appears to us that, while not ignored within the wind engineering sphere of interest, the predominance of architectural and air quality applications means that there is far greater interest in the mechanical responses of buildings or pedestrians and the particulate density profile of building wakes than there is in the reaction of aircraft. Similarly, most meteorological interest is in wind as a transport or damage mechanism where the vorticity of turbulent flows is not a key focus.

Consequently, many wind sensors and the data they produce essentially reduce the longitudinal, lateral and vertical components of interest to us into simply a mean wind speed with a gust element blowing from a mean direction – that is, essentially a single component. Treating wind this way has many advantages for mathematical modelling of otherwise chaotic flow, particularly for statistical treatments that then serve as inputs for more deterministic assessments such as for metal fatigue, pressure loadings or pollutant transport calculations.

However, AusALPA is concerned that the standard single component statistical treatment of turbulent flows may well understate the consequences when an aircraft encounters the reality of three component turbulent flows, particularly given that any reaction to horizontal wind shears may well be exacerbated by the presence of vertical shears.

We are concerned that some of the presumed outcomes of the architecture-based research that are widely accepted for wind assessments of the consequences of building developments in urban spaces may not be as usefully correlated to the real life consequences for aircraft operations. Two examples illustrate this concern.

First, SLR Consulting Australia Pty Ltd produced a largely excellent document that formed the research background to the NASF process. That document is titled *Guidance Material - Building-Induced Wake Effects at Airports Working Paper*[5] ("Guidance Material") and underpins NASFG "B" and attendant wind assessments. Section 6 of the Guidance Material deals extensively with wake characteristics behind buildings and refers on a number of occasions (including in the synopsis) to the height of the building wake. There is also adequate caution about the consequences of building shape and orientation. The NLR report graphically illustrates[6] the shape effect where adverse wind deficits were computed at wake heights of 1.5 to 3.4 times the building height for a 16m building some 330m off the runway centreline for a 23kt wind.

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5 Department of Infrastructure and Transport (DIT) 2012, *Guidance Material - Building-Induced Wake Effects at Airports Working Paper,* SLR Consulting Australia Pty Ltd Report Number 670.10044_R1R1, 17 December

6 NLR-TP-2010-312, *op. cit.*, Figure 6.21 page 89

Despite this cautionary evidence, the wind assessment for 9 Molonglo Drive (a building of 32m building some 375m off the runway centreline) was conducted only at the proposed building height of 32m, solely based on Figure 30 of the Guidance Material. In the NLR example, choosing such a single assessment height would have totally missed the wake structure!

Second, a paper presented by Melbourne and Kostas to the 16th Australasian Wind Engineering Society Workshop in July 2013 (Attachment 6) suggests that the effects of horizontal, lateral and vertical shears on aircraft are significant, particularly in regard to the scale of the wake structures, and appear to persist to far greater distances downwind than the NASFG "B" data suggests[7]. Undoubtedly, the implication that wind assessments may be underestimating both the structure and length of building wakes is of immediate concern to us.

In the main, we are cautious about the application of research based on simple rectangular buildings to circumstances where the shape and/or orientation of the building or of surrounding buildings are not simple. The buildings abeam the threshold of RW 12 at Canberra, shown in Figure 53 of the Guidance Material, are of a shape as problematic as the Schiphol engine run facility and just as likely to violate all of the simplifying assumptions of much of the baseline science.

On the other hand, AusALPA notes that wind assessments such as that conducted for 9 Molonglo Drive assume the absence of topographical influences beyond the effects of surface roughness caused by trees and urbanisation. In the case of Canberra Airport, terrain effects due to Mts Ainslie and Majura, Black Mountain and even the Brindabellas cause various levels of background turbulence that may or may not exacerbate the turbulence contribution of 9 Molonglo Drive. It seems sensible to conduct a reasonable assessment of the baseline turbulence for the whole airport so as to better understand the significance of any turbulence contribution (or reduction) a proposed development might make.

Given that land use planning and approval processes necessarily involve projecting a future post-development state, wind assessments require simulations based on mathematical or physical models to apply the accepted science. AusALPA is concerned about a number of aspects of that modelling process.

The Assessment Methods

Sensors

The Guidance Material canvasses a range of assessment technologies for determining the consequences of typical wind interactions with buildings. The antecedents of those technologies are in industrial and architectural wind engineering. In terms of direct sensor measurements of wind tunnel model flows, the discussion includes single axis Irwin sensors and hot wire anemometers based on their commonality but lacks any discussion on suitability for the specific aviation-related task.

AusALPA maintains the view that three-component simultaneous assessment is essential for aircraft-related applications and we note that there is no mention of multi-component hot wires or multi-hole pressure probes that measure multiple flow components despite over four decades of availability. While undoubtedly unintended,

7 Melbourne W.H. and Kostas, J., 2013, *Embedded Turbulence in the Wake of Buildings Affecting Aircraft Operations,* 16th Australasian Wind Engineering Society Workshop, Brisbane, 18-19 July

we see the Guidance Material as inappropriately implying that assessments conducted using single-component hot wire anemometers, as is the case for 9 Molonglo Drive, are sufficient whereas we believe that the use of such probes does not reflect the best science.

In our view, the Melbourne and Kostas paper mentioned earlier provides ample evidence of the need to properly examine building wakes as three component flows with a range of flow structure sizes rather than single axis flows with relatively high frequency embedded turbulence. It also highlights the need for further scientific research into aircraft responses in such flow structures.

Wind Tunnel Models

AusALPA notes that the 9 Molonglo Drive wind tunnel model is scaled such that the model radius is limited to about 375m[8], conveniently excluding the Qantas hangar which we consider is probably the greatest source of building-induced turbulence for landing on Runway 35.

That exclusion has the effect of distorting the baseline turbulence assessment for the critical runway assessment zone. For this MDP, the outcome for the current Runway 35 threshold may not be directly affected but it may well come into play should the threshold be moved further south on the existing surface as a future development. By then, if the building exists, the problem may have become intractable.

We note that neither the Guidance Material nor NASFG "B" speak to the selection of wind tunnel model scales, presumably leaving the subject to "best practice" and the altruistic diligence of the assessing entity. That may be entirely appropriate given that the Australasian Wind Engineering Society (AWES) has published a "best practice" Quality Assurance Manual[9] which "provides guidance to the practicing construction industry professional on the conduct of wind tunnel testing for buildings and structures". However, no specific guidance on NASFG "B" type wind tunnel modelling is provided – unsurprising given the age of the Manual and the recent implementation of the NASF – but AusALPA is hopeful that AWES may see fit to address this crucial application.

In any event, AusALPA recommends that any assessment reports intended to support the MDP approval process should include a brief note about any factors that may influence the choice of model scaling and any consequent limitations of the results.

Threshold Characteristics for Excessive Turbulence

The Guidance Material faithfully reproduced[10] the NLR researchers' recommendations for threshold values of longitudinal and lateral wind deficits and for turbulence intensity. Those recommendations were:

> Along the aircraft track the speed deficit due to a wind disturbing structure must remain below 7 knots. The speed deficit change of 7 knots must take place over a distance of at least 100m.
>
> Across the aircraft track the speed deficit due to a wind disturbing structure must remain below 6 knots. The speed deficit change of 6 knots must take place over a distance of at least 100m.

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8 Compared to 900m used for the recent T2/T3 Ground Access Solutions and Hotel MDP, Domestic Terminal, Sydney Airport.

9 AWES 2001, *Wind Engineering Studies of Buildings*, AWES-QAM-1-2001, Sydney.

10 DIT 2012, *op. cit.*, page 45

> Surface roughness: the gust/turbulence components in horizontal direction caused by a wind disturbing structure in combination with the meso-scale surface roughness must remain below RMS values of 4 knots.

The NLR research study was conducted using aircraft simulators using autoland capabilities and was limited to landings only. Take-off and, more critically, go-arounds were not considered. No generalised assessment volume for the heights from runway surface to 200 feet was established. These limitations were imposed to constrain the study for reasons of time and costs and were imposed in a land use management environment at Schipol that is highly regulated by a specific Act and regulations.

Inexplicably, NASFG "B" adopts only one of the **three** criteria, the 7kt longitudinal speed deficit, but treats it as if it was the lateral deficit! The Guideline ignores the two related criteria, the 6kt lateral speed deficit and the 4kt RMS turbulence intensity, most likely to be implicated in a high speed runway excursion and possible hull loss. In practical terms, each criterion has safety implications:

- the 7kt longitudinal deficit may result in a go-around, a heavy and possibly structurally damaging landing or a long landing with possible overrun;
- the 6kt lateral deficit may result in a go-around, engine pod strikes or directional control difficulties that may lead to running off the side of the runway with possible structural damage or even hull loss; and
- the 4kt RMS turbulence intensity is the boundary between moderate and severe turbulence which will affect the general controllability and flyability of the aircraft and may result in a go-around or a range of handling difficulties that may endanger the aircraft.

AusALPA strongly asserts that adopting only one of the recommended criteria cannot be, and has not been, justified on the available evidence. All building-induced turbulence assessments based on only one of the three critical threshold criteria potentially ignore significant risks to achieving safe operations in adverse conditions. The illusion that a proper investigation has taken place is unsafe, as is any decision made under that misapprehension.

A practical example highlights our point. Following our initial discussions, Canberra Airport Pty Ltd voluntarily included an examination of the 4kt RMS criteria but apparently chose not to investigate the 6kt lateral wind deficit. Problems were subsequently identified with both the background and the building-induced turbulence intensity.

The Critical Zone for Building Positioning

It is important to reinforce that the NLR study did not define an assessment volume for building-induced turbulence, nor was it ever intended to do so. The study method was limited to effects on approaching and landing aircraft only and, to remove variability to the maximum practical extent, used the certified automatic landing capability of the test aircraft. The study specifically did not examine the turbulence effects on aircraft transitioning from approach and landing to going around or for flight paths off the centreline, an area that AusALPA asserts must be considered to properly manage the operational risk of building-induced turbulence.

The NLR study did validate a land use control zone specifically intended to identify buildings that should be subject to close examination given their potential to produce adverse turbulent wakes and shears affecting runway operations.

ICAO Annex 14 Obstacle Limitation Surfaces

NLR began their study by examining whether the ICAO Annex 14 specified Obstacle Limitation Surfaces (OLS) [11] would also act as a land use control for building-induced turbulence.

The design of the OLS presumes that, in certain situations, aircraft may fly just above those surfaces in normal operational circumstances. Those circumstances are such that the flight path flown during aircraft approaches and go-arounds will not necessarily be constrained to the runway centreline and go-arounds may be initiated at any point of the approach and landing, including after touchdown. Consequently, the OLS is intended to prevent obstacles intruding into the airspace that an aircraft might reasonably occupy as a consequence of system and instrumentation errors as well as normal operational manoeuvring. Separately, we believe that the OLS also defines a volume of airspace that should be as protected as much from excessive man-made turbulence as it is protected from penetration by obstacles.

NLR determined that, although never defined for that purpose, the OLS provided a sufficient constraint to protect the approach airspace above 200ft from the adverse effects of building-induced turbulence. They also determined that the OLS offered no useful constraint for the airspace below 200ft[12].

The NLR-defined Critical Zone for Building Positioning

Based on their research, NLR defined a land use control zone based on a sloping surface with a gradient of 1:35, below which any building would have negligible turbulence effects on the runway[13]. That critical zone for building placement is:

> bounded by a disk-shaped segment with origin in the center of the runway threshold and radii of approximately 1200m (perpendicular to runway centerline) and 900m in front of the runway threshold…extending up to 1500m aft of the runway threshold.[14]

The otherwise excellent Guidance Material inexplicably on page 96 reduced the area of the critical zone for building positioning with respect to potential building-induced wake effect problems from the **1500m** along the runway recommended by the Dutch researchers to only 500m.

The author of the Guidance Material is unable to explain to us how this came about, but there is no doubt operationally that 500m does **not** cover the high risk exposure area of aircraft operations during landing, high speed rollout or late go arounds, particularly when approach and landing conditions are difficult. The error is highlighted by juxtaposing the Guidance Material critical zone with a typically defined touchdown zone and with an overlay of the correct NLR critical zone for building placement for runway 35 at Canberra airport as shown in Attachment 1. It should be noted that the

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11 See ICAO 2013, *op. cit.*, Chapter 4 *Obstacle Restriction And Removal*

12 It is noteworthy that Figure 60 of the Guidance Material identifies two Canberra Airport building with known adverse turbulence effects, the buildings abeam the threshold of RW 12 and the Qantas Hangar abeam the touchdown zone of RW 35, as both penetrating the OLS transitional surfaces. 9 Molonglo Drive appears to be just meeting the transitional surface, which the NLR research clearly indicates as problematic for building-induced turbulence.

13 NLR-TP-2010-312, *op. cit.*, page 6

14 *Ibid*., Executive Summary, page 2

touchdown zone considered by NLR was even longer than shown and ended 915m from the threshold, based on autoland certification.

While the NASF embodies this reduced critical zone based on the erroneous advice in the Guidance Material, AusALPA asserts that all building-induced turbulence assessments based on the critical zone adopted in NASFG "B" potentially ignore risks that are of equal significance to those caused by buildings adjacent to the first 500m of the runway. This can also easily be seen from Attachment 1 - if the new Terminal was being proposed today, it would not be assessed for building-induced turbulence despite its proximity to the RW 35 touchdown zone simply because it is laterally more than 500 metres from the threshold. AusALPA considers that situation to be unacceptable.

The Airspace Assessment Volume

As discussed previously, a critical zone for building positioning relative to the runway is identified in NASFG "B", albeit erroneously truncated at 500 rather than 1500m from the threshold. It is solely a land use control identification surface anchored to the runway centreline. It tells us nothing of what we might encounter in flight other than on the centreline, despite the potential for quite normal flight path deviation during go-arounds.

As indicated in the earlier discussion on operational issues, an aircraft could reasonably be expected to fly anywhere down the ICAO Annex 14 defined approach surface[15] before either completing a landing or going around for another approach. A go-around could be commenced at any point of the approach and even after touchdown and the aircraft could stray considerably off the runway centreline during a go-around due to wind, pilot handling or both. Our considerations must include visual approaches in the typical Australian fleet, not just the more modern types.

In some ways it is unsurprising that neither the Guidance Material nor NASFG "B" specifically deal with the ground footprint or volume of airspace surrounding the runway that should be examined for excessive turbulence. However, it is disappointing that more practical operational advice wasn't given about the need to extend the narrow plane of NLR consideration to a more broadly specified airspace assessment volume consistent with operational reality. It appears to us that, in the absence of specification, a number of wind consultants have assumed that the implied footprint of the assessment volume is the runway surface and approach path abeam the critical zone for building placement.

AusALPA does not agree with this implied footprint assumption.

As we have previously identified, specifying such a footprint was not considered in the NLR research because the research design did not require it. However, NASFG "B" is intended as a management tool for operational risk and must therefore cater for proper hazard identification and risk mitigation within the airspace that aircraft might reasonably be found in normal operations – essentially the design criteria for the OLS.

Consequently, AusALPA recommends that the appropriate footprint for the assessment volume should be the relevant portion of the runway strip (normally 300m wide for the

15 Given the focus on the height band from the surface to 200ft, the ICAO PANS-OPS instrument approach design surfaces were not considered to be as relevant as the Annex 14 surfaces for visual (and by default the higher classes of precision) approaches.

runways of immediate concern) plus 1500m[16] of the approach surface from the runway end and extending to 1500m down the runway from the threshold. Consistent with the OLS design, that footprint should extend from the surface to 200ft (61m) bounded by the ICAO-designated transitional surfaces but continuing through the inner horizontal surface[17]. At that height, the width of the airspace assessment volume is 1154 metres.

The proposed airspace assessment volume based on the OLS is shown overlaid on Canberra airport for runway 35 at Attachment 2.

A comparison between the critical zone for building placement and the proposed airspace assessment volume for turbulence induced by those buildings is shown overlaid on Canberra airport for runway 35 at Attachment 3.

Identifying the Extent of the Hazard

The major building developments at Canberra airport from the terminal south to 9 Molonglo Drive all have the potential to generate turbulence across the touchdown zone and the late go-around airspace. A number of buildings penetrate the NASFG "B" 1:35 rule already and 9 Molonglo Drive is almost three times higher than buildings that the 1:35 surface treats as no risk.

Accurate re-measurement of the Windtech distance data identified significant differences: the eastern edge of 9 Molonglo is only 375m from the centreline and the south eastern edge is only 500m from the future threshold. Unsurprisingly, that means the eastern edge of the building essentially meets the OLS transitional surface at 32.14m, which guarantees that 9 Molonglo Drive will affect parts of the OLS airspace for most winds experienced at Canberra airport.

AusALPA notes that this proposed development is almost an identical scenario to the building placement that gave rise to ATSB Transport Safety Report AO-2010-008 in relation to the buildings abeam the RW 12 threshold and replicates the Annex 14 OLS scenario that NLR modelled and found likely to generate unacceptable levels of building-induced turbulence. It is difficult to accept that the similarities between the building parameters of 9 Molonglo Drive and those discussed in the NLR investigation purportedly deliver such profoundly different outcomes at the runway centreline.

There is no doubt that aerodynamic modelling is required to assess the consequences of building-induced turbulence on airport operations. Computational modelling still lacks adequate validation. The wind tunnel model(s) need to allow an understanding of the existing building-induced turbulence so that the contribution of 9 Molonglo Drive can be properly assessed. It is possible that its contribution may exceed one or more of the three threshold criteria if modelled/assessed in relative isolation from the existing buildings, precluding MDP approval. However, we readily acknowledge that its contribution in a properly modelled/assessed existing environment may be found to be no more than what currently exists, thus permitting further consideration for approval.

The wind assessment for 9 Molonglo Drive was conducted as a single line of data points, i.e. a single dimension, along the runway centreline at a height of 32m (105ft) for a total distance of what appears to be about 600m - a very small 1-dimensional part of the required 3-dimensional assessment volume - and omits examination of the

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16 While the normal approach slope passes through 200ft around 900m from the threshold, allowance must be made for approaches that are below slope. This distance caters for 100ft low, but 1200m to cater for a 50ft error may suffice.

17 For practical purposes, the manoeuvres with which we are concerned are most unlikely to be flown so far off-centreline to stray outside the transitional surfaces below 200ft.

cross-track wind deficit[18]. It is a totally inadequate investigation of an at-risk airspace volume some 3000m long and 300m wide on the ground expanding to about 1150m wide at the required upper height of 200ft (61m). There is no experimental confirmation in the Windtech assessment that the single line of data points is indicative of the flow fields in other parts of the assessment volume and nothing in the literature suggests that it might be so.

For comparison, the wind tunnel model coverage is overlaid on the critical zone for building placement for runway 35 in Attachment 4 and the proposed airspace assessment volume for runway 35 in Attachment 5.

AusALPA strongly asserts that the assessment must include measurement of along-track and across-track wind deficits as well as RMS characteristics for sufficient runs to confidently map the areas of excessive turbulence within the airspace assessment volume. The assessment should include a range of wind speeds and directions to ensure that there are no low-speed limiting phenomena as well as high-speed events.

Although we don't know the extent of the consequent turbulence, AusALPA has absolutely no doubt that part of the existing OLS protected airspace beginning overhead 9 Molonglo Drive will be severely compromised by the wind flowing over the building. We recognise that the energy state of any aircraft between the runway and that OLS boundary will not be as low as that of an aircraft in the flare and touchdown phase of an approach over the runway, but nonetheless it will still be relatively low. This is not an area that the Dutch researchers explored, as they clearly noted, but we need to know what turbulence criteria can be reasonably accepted in that low altitude airspace volume for the likely phases of flight other than landing.

Critically, that situation cannot be ignored but we do not believe that there is sufficient valid data to even identify the risk across the airspace assessment volume, let alone to consider any solutions. Once the flow fields within the volume are mapped, the proponents of 9 Molonglo Drive need to make a safety case in regard to those parts of the assessment volume that are compromised by the building-induced turbulence to justify approval of the MDP.

Risk Assessment and Mitigation

While the concept of creating pass/fail criteria for a single line of data points at a fixed height above the runway centreline may be bureaucratically attractive, it represents an insignificant snapshot of the actual turbulence field. Examining the whole assessment volume will create a 3-dimensional snapshot (accepting that the flows are time-dependent) of what may be encountered within that volume, parts of which will be acceptable and parts of which will be potentially unsafe for aircraft.

Operational and developmental compromise will be a necessity: on the one hand, we have no desire to declare a large volume unsafe because some small and/or little used portion of that space is compromised, but on the other, we cannot accept a development that creates an excessive proportion of compromised space. Striking a balance between the two objectives requires a formal risk management process for which there is currently no legislated provision. The extent and the intensity of the turbulent flows cannot easily be predetermined and the safety case should not be pre-empted by inappropriate assumptions.

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18 The assessment originally ignored the RMS values as well, simply because the NASFG "B" didn't include it.

AusALPA is of the view that consideration of the safety case requires consultation with a group that provides an appropriately wide range of operational expertise. We do not believe that refining the requirements and determining an operationally acceptable outcome is a matter that can be left to the portfolio agencies, as is currently the case.

Meteorological Data

Neither the Guidance Material, the underlying research nor NASFG "B" specify which of the available meteorological data sets should be used in identifying the likelihood of operationally constraining building-induced turbulence being created. Wind data that is suitable for industrial and architectural 'aerodynamics' is mined for a completely different outcome than that suitable for aerodynamically responsive bodies such as aircraft. We are interested in phenomena that last for between 2 and 10 seconds which may well be lost among data averaged on a monthly or annual basis or may not be adequately replicated by standard climate models.

AusALPA does not believe that the technique used in the wind assessment for 9 Molonglo Drive of choosing one or two winds from the BoM monthly or annual data and then testing for threshold wind deficits is the most appropriate investigative approach. In our view, measuring only a single component of the turbulent behaviour of the wake leaves more critical components unexplored, while the choice of one or two input values is error-prone with potential safety implications. Rather, we believe that a range of wind speeds and directions consistent with the operational choice of the active runway should be investigated for critical wind shears and wake impingement before the likelihood of encountering such a wind is considered.[19]

Choosing an appropriate return period (a function of the probability of exceeding a particular wind speed) is essential to achieving a practical operational outcome. While a maximum speed unlikely to be exceeded more than once in 500 years may go a long towards ensuring that a building won't blow down, such a long return period has no relevance in a scenario that has exposure times normally measured in seconds or at most a few minutes.

If a critical wind speed and direction that breaches the threshold criteria is identified, then the likely period of that known hazard to safe aircraft operations on any particular day must be established. Unlike architectural, agricultural and pollutant applications, aviation is conducted within a well-established international framework of relatively timely meteorological advice that mean that reporting and forecast accuracy statistics are more relevant than historical climate data.

AusALPA suggests that determining the relevant exposure time to properly measure the risk is much more of an operational issue than an engineering problem and may require specific statistical analysis of raw Bureau of Meteorology data, rather than compromising by using existing data products generated for unrelated purposes.

Independent Technical Review

AusALPA acknowledges the good faith demonstrated by Canberra Airport Pty Ltd in broadening their assessment as well as allowing us to seek an independent technical review of their subsequent wind assessment report. Our intention in seeking a peer review was to offset our lack of specialist knowledge and to clarify some issues that

[19] Decision criteria for multiple runways such as Sydney's 20kts with pilot discretion to 25kts are planning rather than absolute criteria and should not be used to avoid investigating winds up to a more practical limit of around 35kts.

could not be adequately resolved in our technical discussions with the wind assessment author. For the most part, the review supported our concerns.

Separately, the review also highlighted what we believe to be a significant procedural weakness in the MDP approval process. AusALPA believes that all NASFG "B" wind assessments are presently but quite inappropriately treated as gospel. Our research shows the available assessments to be quite variable in their quality and transparency. Quite reasonably, the portfolio agencies may well lack the technical expertise to challenge either the data or the processes employed. Consequently, we believe that an independent peer review process must be established to ensure that the quality of the technical advice in the wind assessments is best practice.

CONCLUSIONS

AusALPA believes that Canberra Airport Pty Ltd has attempted to meet their responsibilities in regard to NASFG "B" but have been limited by the technical knowledge and operational understanding within both their company and that of their chosen wind consultants. We believe that NASFG "B" is technically deficient, which is a much bigger issue that cannot be resolved by Canberra Airport Pty Ltd.

Nonetheless, the wind environment at Canberra airport is difficult in strong westerly and north-westerly winds now and we believe that it has been exacerbated in the past by what we see as some inappropriate developments that were never, or at best inadequately, assessed for building-induced turbulence. AusALPA does not accept that incorrect or insufficient guidance should be allowed to repeat that historical land use failure. We do not expect that the portfolio agencies will have sufficient technical expertise to properly scrutinise the necessary wind assessments, but we do expect that offsetting complementary processes will be developed.

While we applaud the vision that led to NASFG "B", serious and potentially misleading errors were made in its formulation. Consequently, despite being based on the NLR report, the guideline seriously misrepresents the research by inappropriately shortening the critical zone for building placement and adopting only one of three related criteria needed to identify the risk.

Furthermore NASFG "B" provides no guidance on what airspace volume should be examined to identify excessive turbulence and no guidance on what constitutes suitable meteorological data for the turbulence assessment.

NASFG "B" needs to emphasise that building-induced turbulence assessments should include a full baseline assessment as well as the assessment of the proposed development and, furthermore, should require the MDP proponent to ensure that the assessors take into account the latest research when conducting the assessment.

AusALPA strongly recommends that the Standing Council on Transport and Infrastructure (SCOTI) authorise a significant revision to NASFG "B" to address the issues we have raised. Given that the NASF is in effect model 'best practice' and an important plank in furthering Commonwealth-State relationships in a complex Constitutional space, we believe that these issues deserve the highest priority.

RECOMMENDED CHANGES TO NASF GUIDELINE "B"

- Immediately adopt all three of the NLR recommended assessment criteria;
- Immediately correct the critical zone for building placement;

- Immediately identify an appropriate airspace assessment volume;
- Immediately identify a requirement for multi-component turbulence assessments;
- Immediately identify a requirement to include a full baseline assessment as well as the assessment of the proposed development;
- Immediately identify a requirement for a safety case to mitigate compromised portions of the airspace assessment volume;
- Immediately develop an independent peer review process;
- Immediately develop an operationally competent and representative safety case risk management group;
- develop a closed loop process that ensures that building-induced turbulence assessments from existing structures are part of the decision-making for runway and related infrastructure developments; and
- Engage with AWES to generate an aviation-related update to the Quality Assurance Manual.

RESOLVING THE WIND ASSESSMENT ISSUE FOR 9 MOLONGLO DRIVE

NASFG "B" in its current form creates an illusion of safety by allowing the real risks of excessive building-turbulence to go unexplored. We would argue that the proponents of buildings that may affect safe aircraft operations have a responsibility that extends beyond mere compliance with a severely flawed guideline.

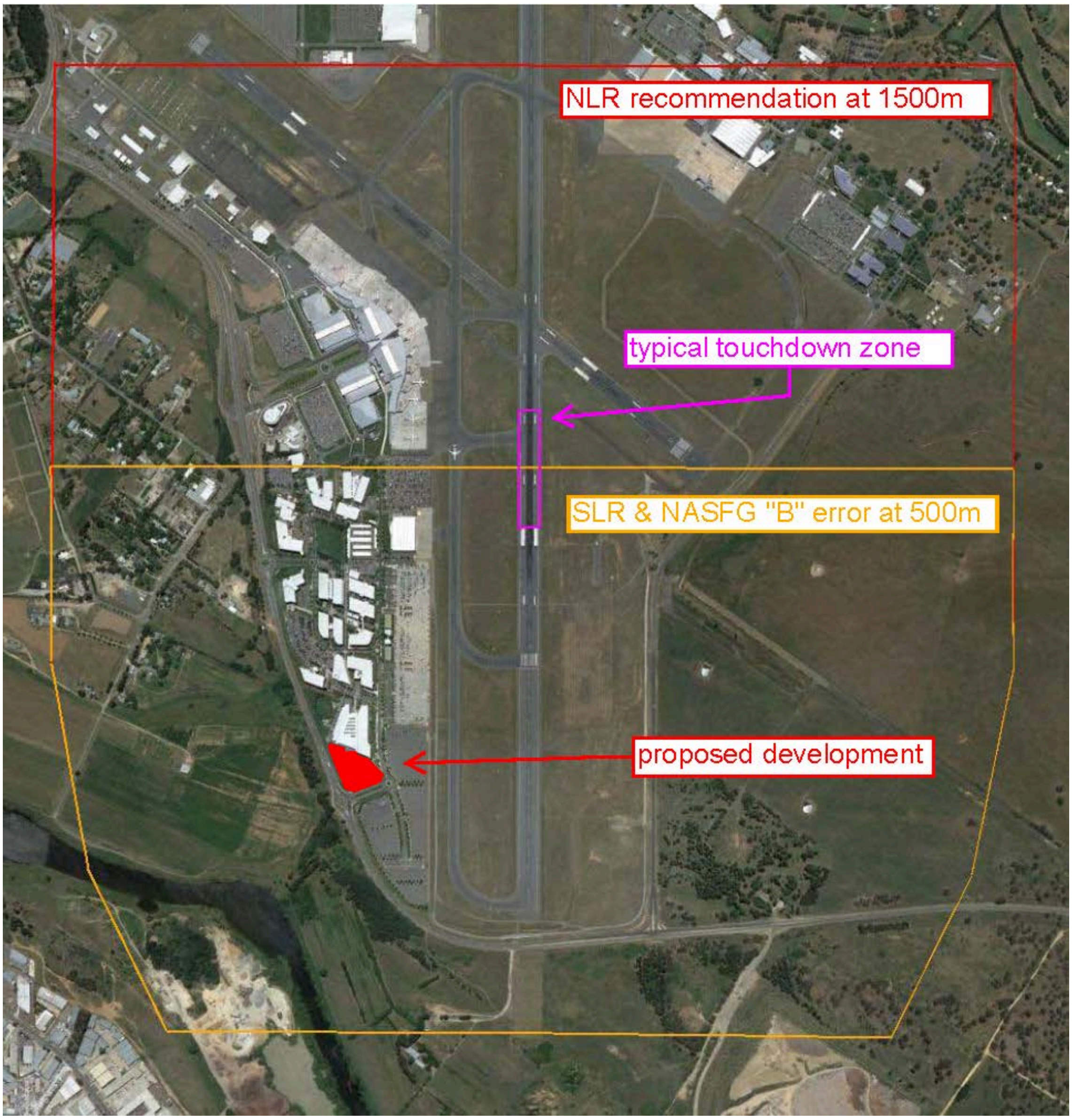
Although hopeful of early resolution, AusALPA does not believe that there is sufficient valid information currently available to support the *Airports Act 1996* approval process for 9 Molonglo Drive, Canberra Airport.

Attachments:

1. Critical zone for building placement – RW 35 Canberra
2. Proposed airspace assessment volume for building-induced turbulence – RW 35 Canberra
3. Comparison between critical zone for building placement and proposed airspace assessment volume – RW 35 Canberra
4. Comparison between Windtech model coverage and the critical zone for building placement – RW 35 Canberra
5. Comparison between Windtech model coverage and the proposed airspace assessment volume – RW 35 Canberra
6. Melbourne W.H. and Kostas J., *Embedded Turbulence in the Wake of Buildings Affecting Aircraft Operations*, Paper presented to the 16th Australasian Wind Engineering Society Workshop, Brisbane, 18-19 July, 2013

Attachment 1

Critical zone for building placement – RW 35 Canberra airport



NOTE: The error made in the SLR Guidance Material and subsequently adopted in NASFG "B" results in a truncated critical zone (shown above in orange) that barely covers half of the normal touchdown zone. Very clearly, the terminal buildings could in a strong north-westerly wind potentially make the touchdown zone operationally unacceptable due to building-induced turbulence.

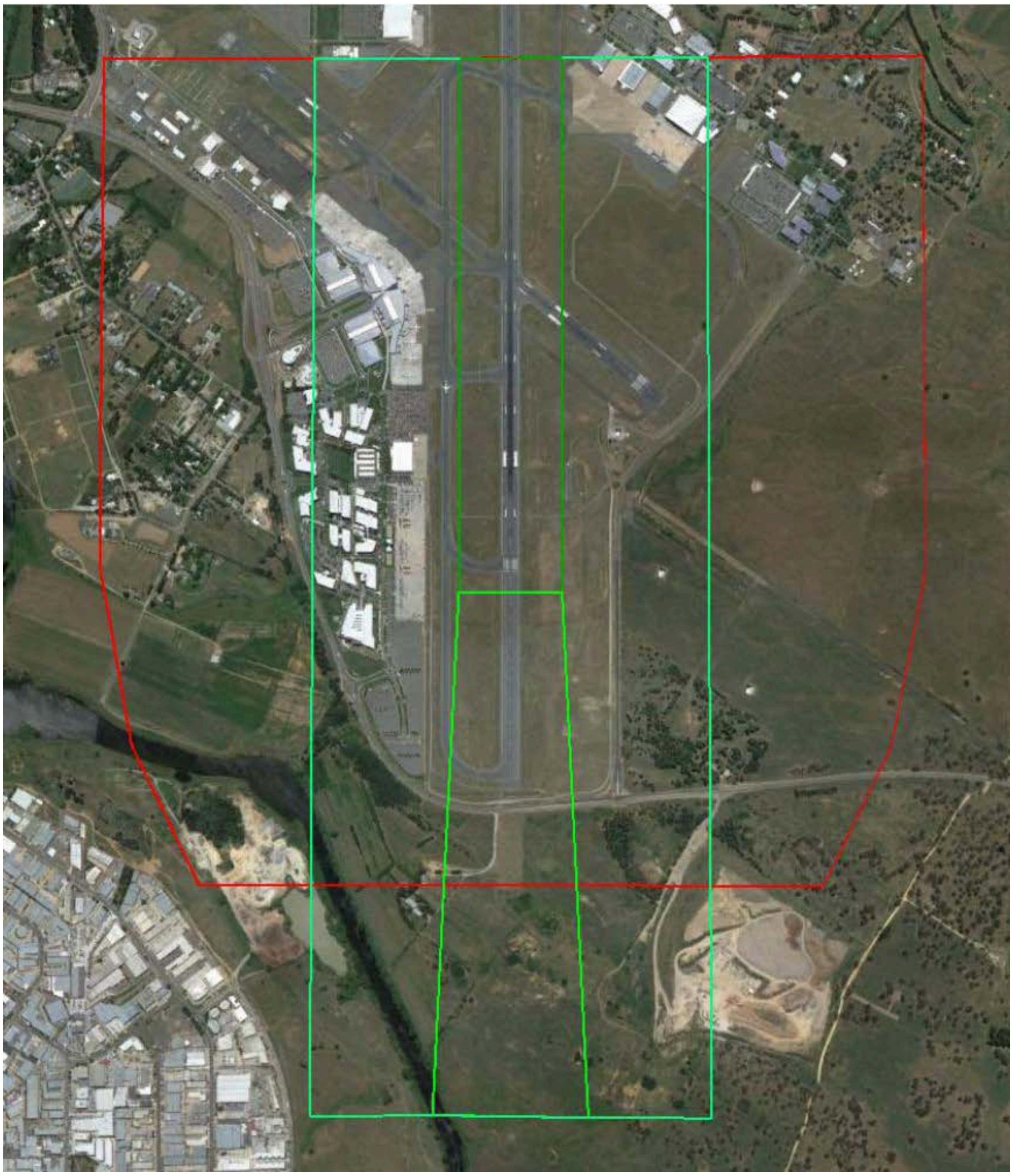
The extension to complete the correct NLR recommended critical zone for building placement is shown above outlined in red.

Attachment 2

Proposed airspace assessment volume for building-induced turbulence – RW 35 Canberra airport

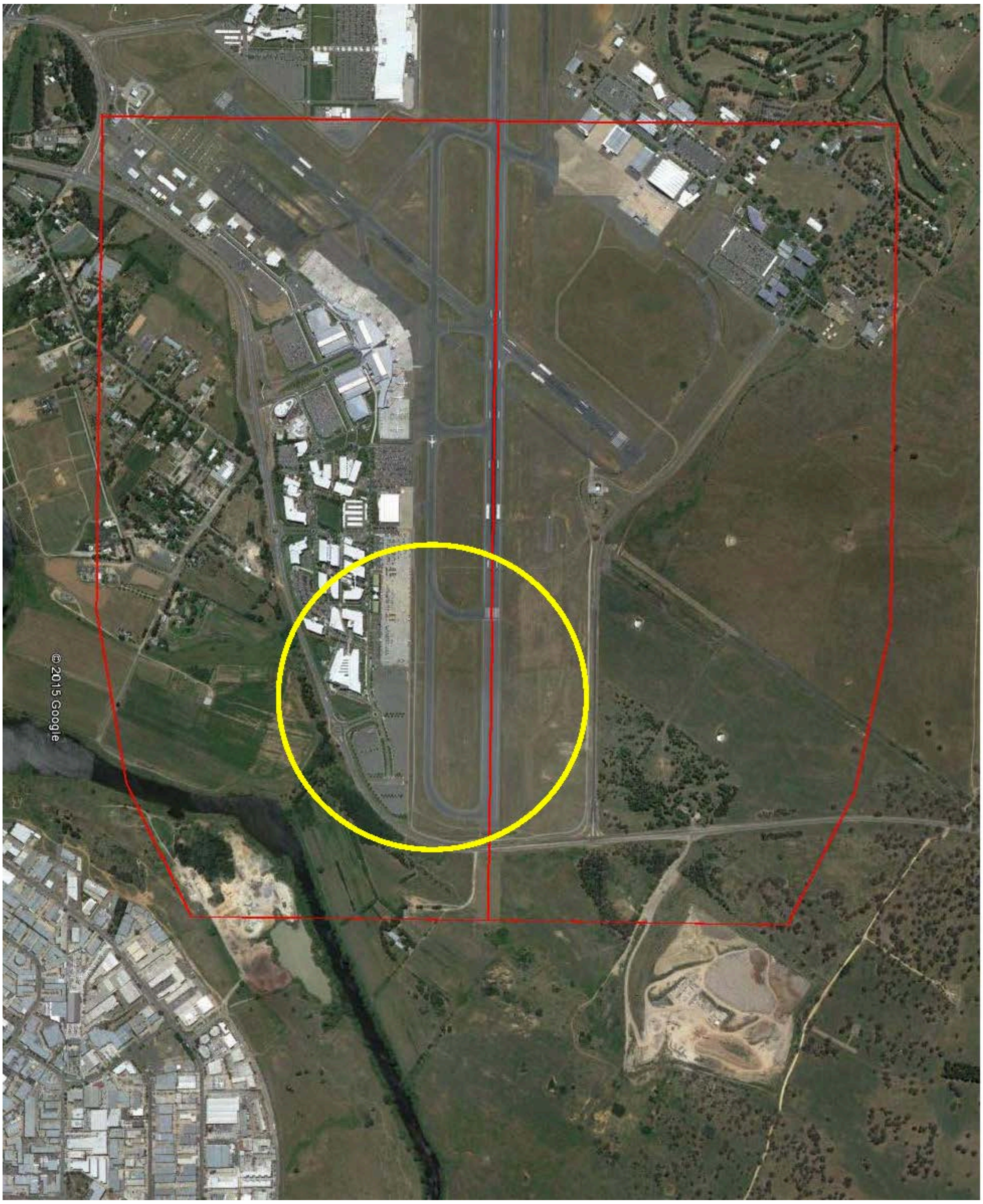
Attachment 3

Comparison between critical zone for building placement and proposed airspace assessment volume – RW 35 Canberra airport



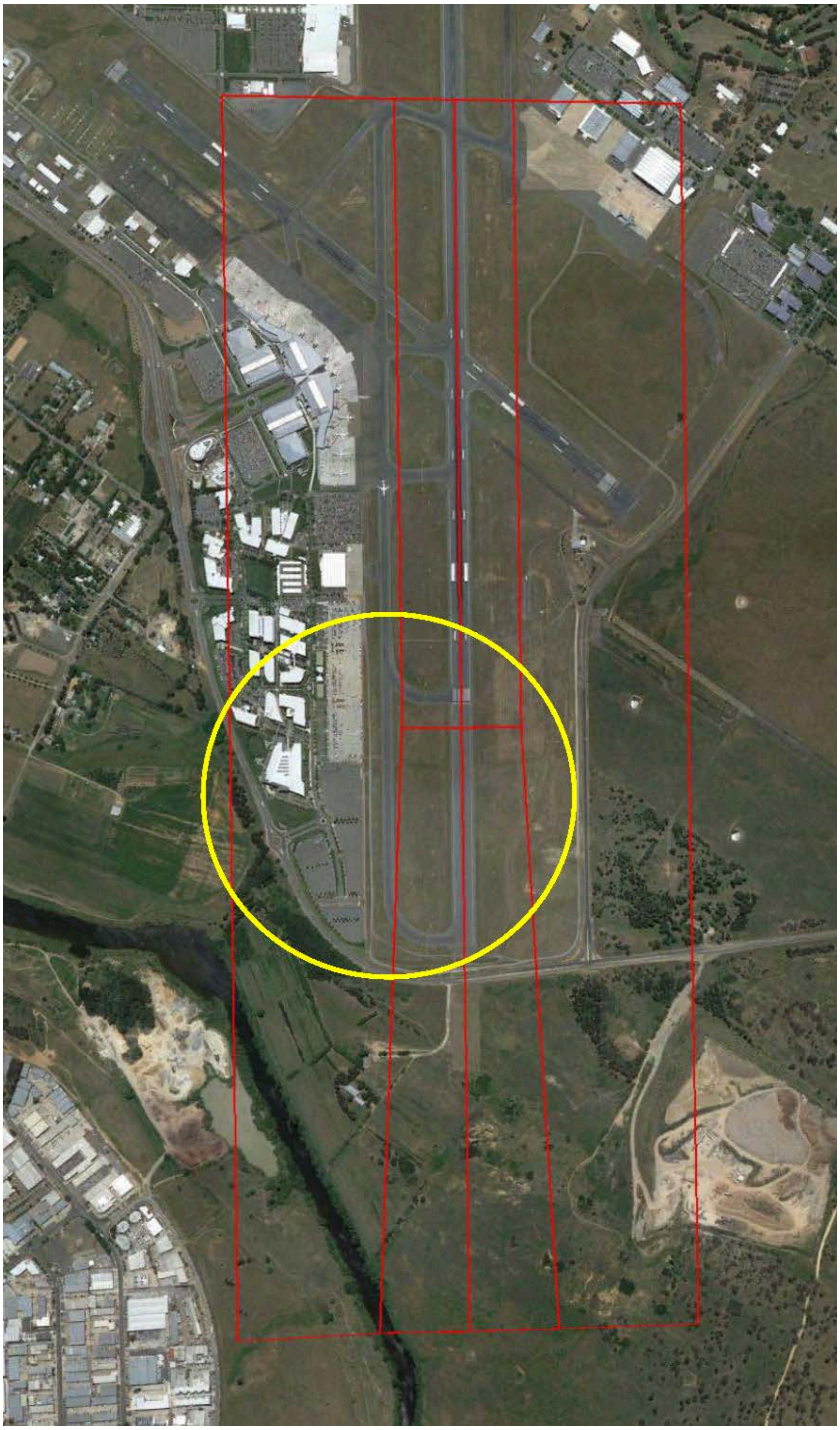
Attachment 4

Comparison between Windtech model coverage and the critical zone for building placement – RW 35 Canberra airport



Attachment 5

Comparison between Windtech model coverage and the proposed airspace assessment volume – RW 35 Canberra airport



16th Australasian Wind Engineering Society Workshop
Brisbane, Australia
18-19 July, 2013

Embedded Turbulence in the Wake of Buildings Affecting Aircraft Operations

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Abstract

To study the magnitude of high, short distance shear flows in embedded turbulence events in the wake of a Building, three component velocity measurements have been made in the wake of a 1/200 scale wind tunnel model of a 240m wide by 60m deep by 35m high rectangular Building. The measurements were made using four velocity measuring probes located downstream of the Building. The time series velocity data were analysed to determine the magnitude of short distance wind shears in embedded turbulence events in the wake of the Building. Short distance wind shears have been presented in this report in full scale dimensions and scaled to relate to approaching wind conditions having a maximum gust wind speed of 10ms^{-1} in an hour at a height of 10m in Terrain Category 2.

Introduction

Relatively coherent vortices are developed in the wakes of buildings and these can develop shear flows with the ability to cause adverse effects on aircraft flying through these wakes, particularly in the landing phase. Longitudinal and vertical shear flows over distances between 20m and 200m along and across the path of an aircraft are of most significance, depending on the aircraft size.

The more extreme vortex or turbulence events are to be found intermittently embedded in building wakes and until the availability of multi-component velocity probes and/or diagnostic measurements have been difficult to measure using wind tunnel models. More specifically, using several such instruments (Turbulent Flow Instrumentation 'Cobra Probe') to measure three component velocity time series at locations a distance apart, it is now possible to capture and define these embedded turbulence events which generate the short distance shear flows of most importance to aircraft response.

Criteria to define when buildings wakes are likely to cause adverse effects on aircraft operations have been developed internationally which are based on mean wind speed shear properties and turbulence intensities, both of which describe only mean properties in the wake flow. Whilst in some of these studies some account has been taken of turbulence events in the wake of a building is has been shown that strong, short distance shear flows, can persist as turbulence intensities and mean shear flows decrease. Hence, in only relating to the mean properties in the wake behind a building, the short distance shear flows in embedded turbulence events that are likely to have the most impact on an aircraft in the critical stages of landing and take-off are likely to be missed.

To provide information on the properties of embedded turbulence events within the wake of a rectangular Building a short programme of wind tunnel measurements and data reduction have been undertaken. These measurements were made in the MEL Consultants 400kW Boundary Layer Wind Tunnel, using a 1/200 scale model.

Model and Experimental Techniques

A photograph of the 1/200 scale model of a 240m wide by 60m deep by 35m high rectangular Building is shown in Figure 1. A plan of the Building is given in Figure 2, along with the location of the four, three component, velocity measuring probes and the velocity measurement definitions. The measurements were made in a model boundary layer of flow over open country terrain (Terrain Category 2 as defined by the Australian Wind Loading Standard AS/NZS 1170.2:2011) and the velocity profiles and turbulence intensities for the incident flow are given in Figures 3 and 4.

Figure 1. Photograph of 1/200 scale building model in the wind tunnel.

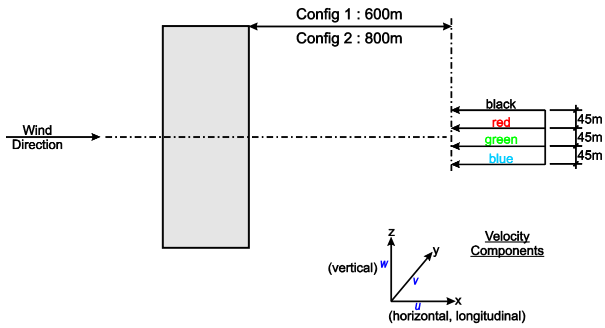

Figure 2. Plan of the rectangular building and location of the velocity probes and velocity measurement definitions.

The three component velocity measurements that will be presented in this report had a minimum resolvable frequency of 2.5Hz, in full scale. All the short distance wind shears evaluated and presented in this report will be based on data with this frequency response and are hence all comparable. However, it is noted that if the analysis had been done with data filtered with a 3 second moving average the wind shear values would have been lower. The velocity measurements were recorded over a time span of 4 hours in full scale time.

The data given in this report are in full scale dimensions and are all scaled to relate to approaching wind conditions having a mean wind speed of 6ms^{-1} and an approximate maximum gust wind speed of 10ms^{-1} in the hour at a height of 10m in open country terrain as defined by Terrain Category 2. Measurements were

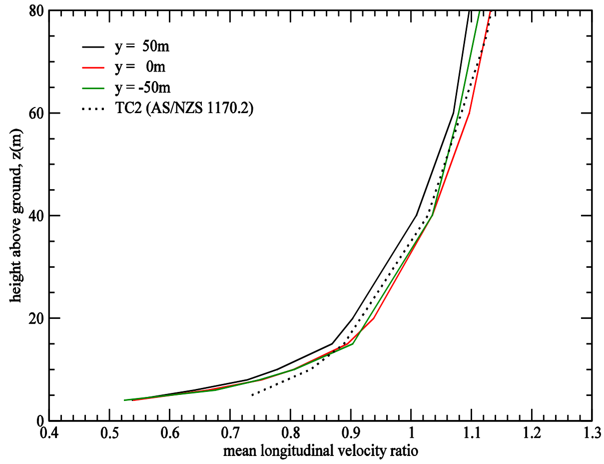

Figure 3. Mean longitudinal velocity profile of the wind tunnel model flow over open country terrain.

made for the wind flow normal to the long axis of the Building and downstream at distances of 600m and 800 m from the centre downstream side of the Building as shown in Figure 2. These two configuration have been designated Configuration 1 and 2 respectively.

The scaling of the model to full scale parameters was determined by using the non-dimensional Reduced Velocity parameter,

i.e. $\frac{V_r}{N_r L_r} = Constant,$

where the subscripted parameters, V_r, N_r and L_r are the velocity, frequency and length ratios of model over full scale.

Overview of Turbulence Intensities

An initial overview of the effect of the Building on the downstream conditions can be seen in the turbulence intensities for the three components, longitudinal (u), lateral (v) and vertical (w) for the configurations measured. The turbulence intensity profiles are given for the incident flow and in the wake at 600m and 800m downstream of the Building in Figure 4. The turbulence intensities are defined as the standard deviation of the velocity components normalised by the mean longitudinal wind velocity, for the full data record.

It can be seen that at the height of the Building (35m) the turbulence intensities in the incident flow are between 60% and 80% of the turbulence intensities measured in the wake of the building and the characteristic is quite different in that the turbulence intensities in the wake do not diminish so rapidly with height. These turbulence intensities are not necessarily an indication of the severity of embedded turbulence events (as the turbulence in the freestream and in a single building wake are generated by essentially different mechanisms); and these records will be analysed for embedded events in the same way as those measurements in the wake of the Building to provide background comparisons.

The highest longitudinal and vertical turbulence intensities can be seen to occur between heights of 30m to 60m. For convenience the detailed analysis of the embedded turbulence events will be done in this report for the building height of 35m.

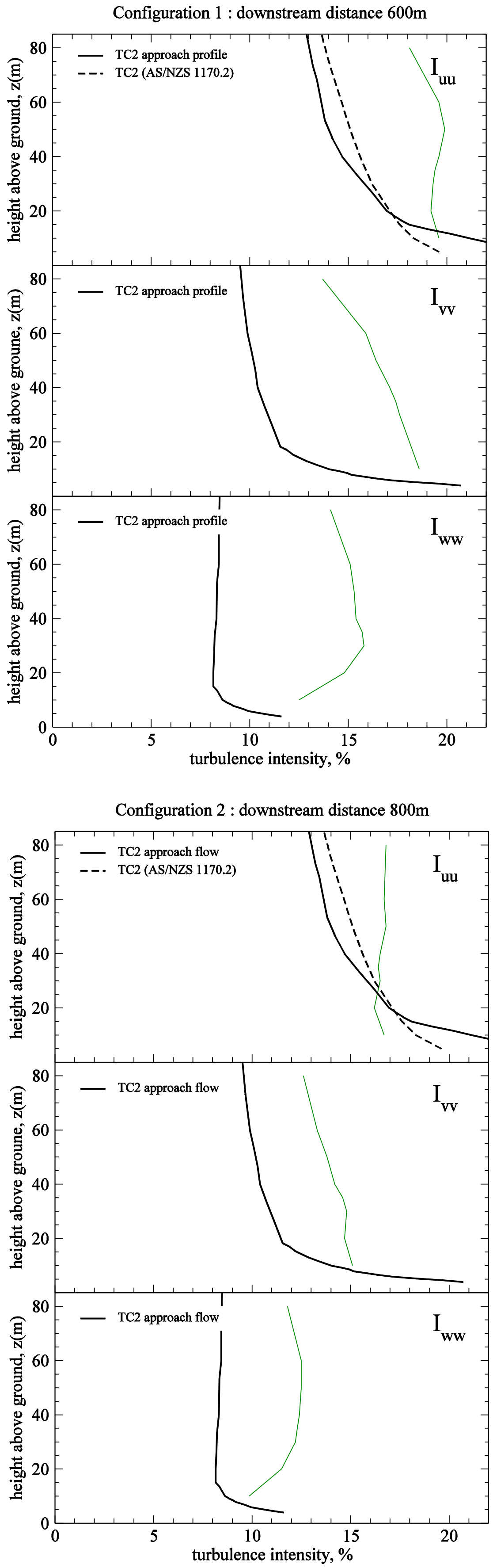

Figure 4. Turbulence intensity profiles for Configurations 1 and 2 at a distance of 600m and 800m downstream of the centre of the downstream side of the building. Terrain Category 2 incident turbulence profiles are also included in each plot.

Detailed Analysis

The detailed analysis was undertaken to characterise the various, short distance wind shears present in embedded turbulence events within the wake flows behind the Building. The process commenced with a visual inspection of the full velocity time series to select one or more 5 minute (300 second) segments including typically high velocity variations in longitudinal and vertical components (u and w). Examples of 300 second segments for the u and v components are given for Test Configuration 1 in Figures 5 and 6. From the 300 second segments, one or more 50 second segments were selected from which to determine typically high, short distance, wind shear values. It is emphasised that whilst typically high wind shear values have been sought, the process to date is manual and higher values may have occurred. Some examples of 50 second segments for Test Configurations 1 and 2 are given in Figures 7 and 8.

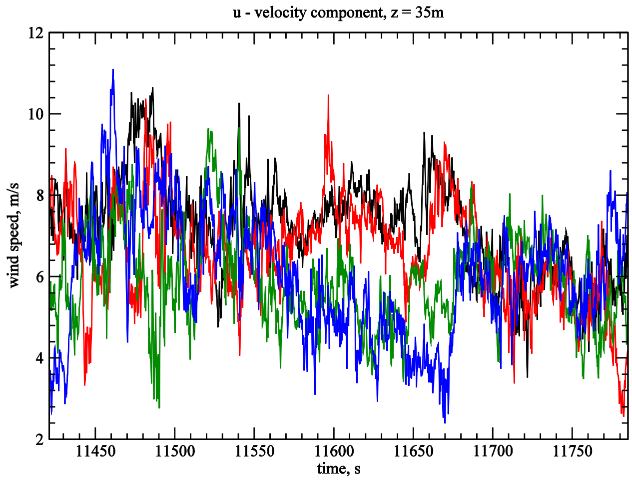

Figure 5. Longitudinal velocity component for Test Configuration 1 for the four probes at a height of 35m above ground and 600m downstream as a function of time over 300 seconds for a reference wind speed with a minimum gust wind speed of 10ms^{-1} at 10m over open terrain.

Example of detailed analysis for Test Configuration 1

From the 300 second segment in Figure 5 a 50 second segment of the longitudinal velocity component from the four probes for Test Configuration 1 is given in Figure 7. Examples of the analysis to obtain the short distance wind shears from this Figure are given as follows:

- At a time near 11486 seconds it can be seen that the black trace is at 10.5ms^{-1} whilst the green trace is at 3.3ms^{-1}. The difference is 7.2ms^{-1} between two longitudinal velocity measurements 90m apart. This is interpreted as a crosswind wind shear of 7ms^{-1} over 90m normal to the wind direction.

- At a time near 11462 seconds it can be seen that the blue trace falls from 11.2ms^{-1} to 4.4ms^{-1} over a time of 9 seconds, or from 9.6ms^{-1} to 4.4ms^{-1} in 7 seconds. The difference is 6.8ms^{-1} and 5.2ms^{-1} respectively. Given that for a maximum gust wind speed of 10ms^{-1}at 10m in Terrain Category 2, the mean convective longitudinal velocity at 35m would be approximately 7ms^{-1}, the time of 9 and 7 seconds is equivalent to a distance of approximately 65m and 50m respectively. This is interpreted as an alongwind shear of 5ms^{-1} over 50m.

In Table 1 the results of the analysis of the 50 second segments for Configuration 1 and 2 are given as wind shears over short distances scaled to relate to approaching wind conditions having a maximum gust wind speed of 10ms^{-1} in an hour at a height of 10m in Terrain Category 2. The data in Table 1 have been analysed in the same way as described above. As the analysis to date has been done manually there may be higher shear rates than are being given in Table 1.

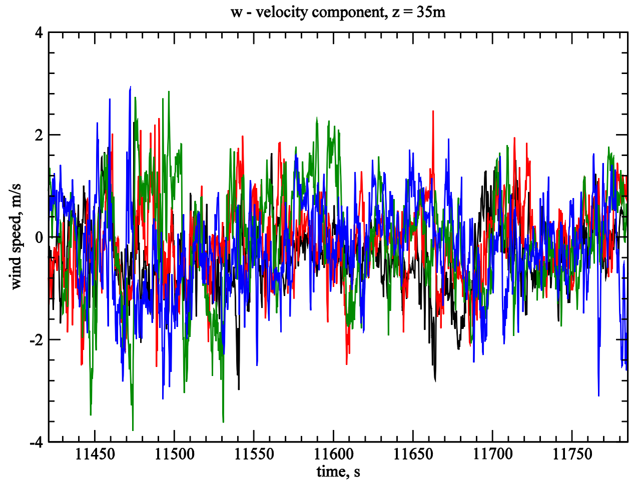

Figure 6. Vertical velocity component for Test Configuration 1 for the four probes at a height of 35m above ground and 600m downstream as a function of time over 300 seconds for a reference wind speed with a minimum gust wind speed of 10ms^{-1} at 10m over open terrain.

Test Configuration	**Wind Direction**	**Height and Distance from Building**	**u-component**		**w-component**	
			Cross-wind	*Along-wind*	*Cross-wind*	*Along-wind*
Incident Flow Open Country	N/A	z = 35m	5ms^{-1} in 135m 3.5ms^{-1} in 90m 3.5ms^{-1} in 45m	4ms^{-1} in 100m 3ms^{-1} in 50m	2.5ms^{-1} in 135m 2ms^{-1} in 90m 2ms^{-1} in 45m	2ms^{-1} in 100m 2.5ms^{-1} in 50m
Configuration 1	Normal to building long axis	z = 35m x = 600m	7ms^{-1} in 135m 7ms^{-1} in 90m 5.5ms^{-1} in 45m	6ms^{-1} in 150m 7ms^{-1} in 100m 5.5ms^{-1} in 50m 5ms^{-1} in 25m	4.5ms^{-1} in 135m 4.5ms^{-1} in 90m 6ms^{-1} in 45m	5.5ms^{-1} in 150m 5ms^{-1} in 100m 5ms^{-1} in 50m 6.5ms^{-1} in 25m
Configuration 2	Normal to building long axis	z = 35m x = 800m	7ms^{-1} in 135m 7.5ms^{-1} in 90m 6.5ms^{-1} in 45m	7ms^{-1} in 150m 5.5ms^{-1} in 100m 5ms^{-1} in 50m	5ms^{-1} in 135m 4.5ms^{-1} in 90m 6ms^{-1} in 45m	5ms^{-1} in 150m 5.5ms^{-1} in 100m 5ms^{-1} in 50m

Table 1. High value, short distance wind shears in the Incident Flow and in the wake of the Building (35m high, 60m wide, 240m long) for approach wind conditions in which the maximum gust wind speed within an hour at 10m in Open Country Terrain is 10ms^{-1} (as defined by AS/NZS 1170.2).

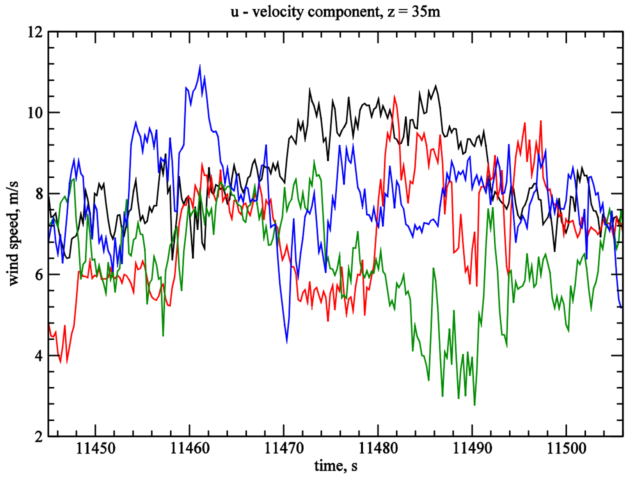

Figure 7. Longitudinal velocity component for Test Configuration 1 for the four probes at a height of 35m above ground and 600m downstream as a function of time over 50 seconds for a reference wind speed with a maximum gust wind speed of $10ms^{-1}$ at 10m over open terrain.

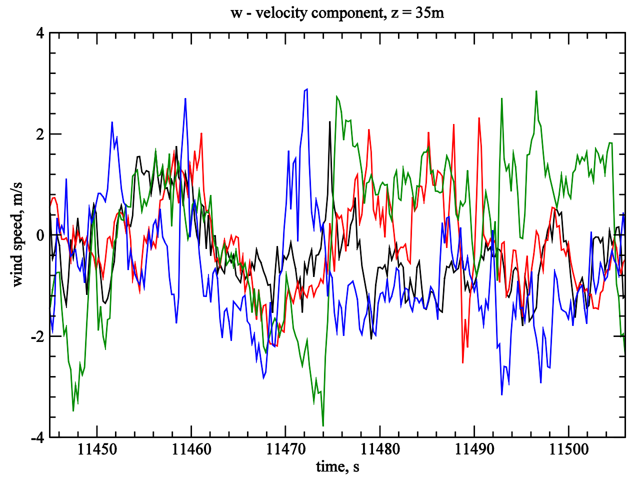

Figure 8. Vertical velocity component for Test Configuration 1 for the four probes at a height of 35m above ground and 600m downstream as a function of time over 50 seconds for a reference wind speed with a maximum gust wind speed of $10ms^{-1}$ at 10m over open terrain.

Conclusions

Three component velocity measurements have been made in the wake of a 1/200 scale wind tunnel model of a 240m wide by 60m deep by 35m high rectangular Building. The measurements were made using four velocity measuring probes located across a line through the centre of the Building for a wind direction normal to the long axis of the Building. These data were analysed to determine the magnitude of short distance wind shears in embedded turbulence events in the wake of the Building. Short distance wind shears have been presented in this report in full scale dimensions and scaled to relate to approaching wind conditions having a maximum gust wind speed of $10ms^{-1}$ in an hour at a height of 10m in Terrain Category 2 as defined by the Australian Wind Loading Standard AS/NZS 1170.2.

Cross-wind, short distance, longitudinal wind shears of approximately $7ms^{-1}$ over distances varying from 45m to 135m have been measured for both 600m and 800m distances downstream of the Building. For an aircraft approaching at $50ms^{-1}$ in $10ms^{-1}$ or $15ms^{-1}$ cross-winds this relates to a 15% or 20% change in wind speed respectively over distances varying from about 50m to 150m. Similarly, along-wind short distance vertical wind shears of approximately $5ms^{-1}$ have been measured over distances varying from 50m to 150m. For an aircraft approaching at $50ms^{-1}$ in $10ms^{-1}$ cross-winds this relates to a differential angle of attack between the two wings of approximately 6^0. Similar scaling of these effects can be done for different approach wind speeds.

References

Australian/New Zealand Standard AS/NZS 1170.2:2011 (Incorporating Amendment Nos 1 and 2), Structural design actions. Part 2: Wind actions