

To: Illinois Department of Transportation

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Re: Rebuttal to Presentations by Professor Corke and Dr. Veillette for CMH Heliport Public Hearings

During the Children's Memorial Hospital (CMH) Heliport Public Hearings on June 24, 2011, Professor Thomas Corke and Dr. Patrick Veillette provided reviews of the report "Analysis of Urban Airwake Effects on Heliport Operations at the Chicago Children's Memorial Hospital" by Horn, Keller, Whitehouse, and McKillip. Their assessment of the study was largely negative and they concluded that the study should not be used in the approval process for the heliport. However, several of their assessments and analyses were either misleading or inaccurate. The purpose of this memo is to provide rebuttal to the criticisms of the study.

The authors acknowledge the fact that the simulation of helicopter flight in an urban airwake environment is a complex problem to analyze, and it is in the nature of such problems that engineering analysts can disagree about the suitability of specific assumptions and methods to be used for analysis and about the degree of conservatism represented by the results. The approach to resolving such disagreements typically involves peer review in the technical literature, discussions at technical symposia, and the extended review process that has led to the body of relevant Federal civil and military regulations regarding rotorcraft operations. As noted in the citations provided below and in the original report, the methods and assumptions we adopted are derived from this body of technical and regulatory information and are described in open publications, embraced by current practitioners in the field, or both.

In their review of the report, Drs. Corke and Veillette provided comments that depart considerably from this constructive approach to technical dialogue regarding the complex problems of flight simulation. As will be discussed in detail below, their comments suggest: unfamiliarity with several key standard practices in the rotorcraft simulation community; misunderstandings regarding which features of rotorcraft operations and flight dynamics are important to safe operation and which are, at most, tangential; advocacy of modeling approaches for complex urban wind fields that are beyond the state of the art of current computational methods; application of unrepresentative and inappropriate metrics for assessing errors in the analysis; misunderstanding of currently accepted flight test procedures for comparable operational situations; and advocacy of changes to the rotorcraft model that are of very doubtful relevance to the problem under study. While our chief focus here is on specific responses to

particular technical criticisms, we also feel it is important to bear in mind the unnecessarily tendentious nature of many of the criticisms offered in weighing their significance in assessing the reported results.

The objective of our study was to perform research of the wind effects (urban airwake) to support a preliminary estimate of operational risks (due to winds/turbulent conditions) associated with flying to the helipad along the proposed flight paths. The nature of this study is multi-disciplinary, drawing from the aerospace engineering fields of fluid dynamics, flight dynamics, and flight simulation. Ultimately, the objective of the study was to provide an assessment of helicopter handling qualities during flight operations near and over the helipad. *Handling qualities* represents a specific discipline within the field of aerospace engineering focusing on the study of the ease and precision with which a pilot can perform an aircraft mission. The relative “ease” or difficulty with which pilots can perform their mission is *pilot workload*.

It is universally accepted that the handling qualities discipline must rely to some degree on qualitative and subjective data, because pilot workload ultimately relies on *pilot opinion*. Whether a piloting task is “difficult” or “easy” is largely a subjective question. The discipline merges both quantitative and qualitative data to provide predictions and assessments of aircraft handling qualities, with final evaluations based on pilot opinion through flight testing. This merging of quantitative and qualitative data can be seen in the U.S. military handling qualities specifications:

“To determine the Assigned Level of handling qualities, test pilots shall use the Cooper-Harper Handling Qualities Rating (HQR) Scale ... to assess the workload and task performance ...”, from Aeronautical Design Standard 33E-PRF, *Handling Qualities Requirements for Military Rotorcraft*, February 2000.

In other words, the handling qualities of military helicopters are ultimately judged based on a subjective pilot rating scale as measured by the widely used Cooper-Harper scale. The same is also true of U.S. Navy Dynamic Interface testing, as was discussed in our presentation at the hearing on June 23, 2011 and later in this memo.

Qualitative or subjective criteria can also be seen in FAA certification requirements. The following are examples of the language in Federal Aviation Regulations (FAR) Part 25 Airworthiness Standards: Transport Category Airplanes:

“Any combined lateral-directional oscillations ...must be controllable with normal use of the primary controls without requiring exceptional pilot skill.”

“Land planes must be satisfactorily controllable, without exceptional piloting skill or alertness, in power-off landings at normal landing speed.”

The term “exceptional pilot skill” appears in numerous places in FAR Part 25. The only way to evaluate this requirement is to gather pilot opinion data. In other words, the certifications of all commercial transport aircraft in the United States rely to some degree on subjective assessments by test pilots.

While some of the specific criticisms are valid in the sense that the predicted flow does not perfectly capture measured wind fields, it is important to understand that the scope of an analysis that would satisfy all such criticisms is beyond the state of the art of helicopter/wind analysis tools currently available. In part because of our recognition of the inevitable limits of the computational models used, we recommended (and pursued) flight testing to obtain data to validate the approach and conclusions to the extent possible in our study. Note that it is not unprecedented to conduct simulation studies without quantitative validation of the simulation model. For example, the Civil Aviation Authority (CAA) in the United Kingdom conducted a study on turbulence around off-shore oil platforms in 2004:

Safety Regulation Group, “Helicopter Turbulence Criteria for Operations to Offshore Platforms,”  
CAA PAPER 2004/03, September 2004.

The CAA study used piloted simulations to evaluate airwake turbulence criteria for offshore oil platforms and resulted in the 4.6 knot limit on vertical velocity standard deviation that was cited in our report and in the study by RWDI. The CAA study did not include *any* quantitative validation of the simulation model. Nonetheless, the CAA used results of the study to define quantitative guidelines for helicopter operations at offshore oil platforms.

Given the above introductory remarks, the following comments are provided with respect to specific criticisms raised by Drs. Corke and Veillette.

**Note that while it is not disputed that the CFD airwake model does not perfectly match the wind tunnel data, we do not agree with all criticism provided by Dr. Corke in his presentation.** The example given by Dr. Corke illustrating “Large Errors in Wind Speed and Vertical Gusts Along Flight Path” (Slide 22 in his presentation) superimposes experimental data on plots taken from our report (specifically Figure 6.2-2). In this plot, the three components of the wind velocity (from the CFD model) along the simulated approach path are plotted, along with the horizontal component of the wind speed. These wind components represent the instantaneous wind velocity at a given point in the simulation. At the point in the simulation where the helicopter transitions to a hovering condition over the helipad (approximately 40 seconds into the simulation), experimental data points are superimposed in which the (experimental) wind speed is 10 knots (approximately 17 ft/sec), where the vertical gust is approximately 30 ft/sec. There are several possible interpretations that could account for a large part of the differences in predicted and measured velocities presented, e.g., displacement of the wind tunnel measurement points relative to the flight path position assumed in the simulation. The fact that the simulation produces a plateau in vertical gust velocities simultaneously with a steep drop in mean wind speeds near the building edge indicates similar qualitative behavior to the experiment, though displaced in time. Full reconciliation of the measurements with the computations could be quite instructive. However, even taking the comparison at face value it is not possible to derive a “911%” error in mean wind speed from the comparison made in the lower plot. The presentation of results here appears to be selected to convey an impression of wild discrepancies with experiment when it is entirely plausible that careful reconciliation of assumed positions for flow field sampling could lead to a conclusion of much more moderate disparities.

**The verification and validation methods used in this study are consistent with verification and validation methods commonly used in the field of flight simulation.** Although details are not provided in our report, the flight dynamics model was exercised extensively to verify that the model was reasonable. The verification tests included:

1. Calculating trim controls, attitude, and power required and ensuring the trends are consistent with those seen with most conventional helicopters. In this case some of these results were provided in the report (Figures 4.4-1 and 4.4-2).
2. Calculating response to step inputs in the primary controls and ensuring that the on-axis responses are consistent with those seen with most conventional helicopters. Some of the important off-axis responses (e.g. yaw-due-to-collective) were also checked to see if they had the right trend.
3. Extracting simplified (“linearized”) models and evaluating characteristic response modes (“eigenvalues”) of the modeled aircraft to ensure the dynamic modes and stability characteristics are consistent with those seen with most conventional helicopters.

The validation study was consistent with what is often seen in articles and reports in the field of flight simulation, i.e. direct comparisons of the time history response from flight tests and simulation. Numerous examples can be found in the AIAA paper database. This method of validation is consistent with validation documentation that reviewed by the authors for several rotorcraft simulation models (including the UH-60A, AH-64, CH-47, and AH-1W flight simulation codes).

**Dr. Corke claimed that the flight dynamic model needed to include dynamic stall, transonic flow effects, aero-elastic blade models, and advanced wake models to accurately predict flight dynamics and pilot control activity. This claim is *incorrect, impractical* for this study, and is *not standard practice* in the field of rotorcraft flight simulation and handling qualities.** It is common engineering practice to use simplified rotor dynamic models for investigations of handling qualities and pilot control activity. Flight simulation models often include many simplifications to improve execution speed (the computer codes must often be executed in real-time for use in flight simulators). However, these simplifications are justified by the requirements of the application. A model should only be as complex as it needs to be for the intended application. In this case the problem domain is well described in the following reference:

Padfield, G.D., *Helicopter Flight Dynamics: The Theory and Application of Flying Qualities and Simulation Modeling*, 2nd Edition, Published by Blackwell Science Ltd, © 2007.

Helicopter dynamics can be classified in terms of the frequency and amplitudes of interest. High frequency dynamics include vibration and acoustics. High amplitude dynamics includes aggressive maneuvering. The dynamics of interest in this study are well within the low frequency / low amplitude domain. As discussed in Padfield’s text, this is a suitable application of a “Level 1” (i.e. simple) simulation model. Thus, a Level 1 helicopter model was developed as described in the guidelines in Padfield’s text.

Dr. Corke described several complex phenomena that he suggested should be included in the model. While these are indeed “real-world effects”, none of them are important for the type of dynamics investigated in this study:

1. Transonic Flow and Dynamic Stall Effects: These effects are only important in high speed or high load factor flight and will not be an important factor for low speed / low amplitude maneuvers as seen in an approach and hover maneuvers.
2. Aeroelastic Blade Models: While elastic blade models are commonly used on Comprehensive Rotorcraft Analysis and Structural Dynamics simulations, flight simulation models almost always use a rigid blade assumption. The dynamics associated with aero-elastic effects are important for vibration and loads calculations, but have little effect on the vehicle body dynamics and pilot control motions in low frequency / low amplitude maneuvers. Furthermore, the model would require detailed structural model of the helicopter blades.
3. Blade Vortex Interaction (BVI): This phenomenon has virtually no effect on flight dynamics. BVI models are used almost exclusively in the study of helicopter noise. Inclusion of BVI models in rotorcraft simulation model for piloted handling qualities studies is beyond the current state-of-the-art.
4. Engine Dynamics: While engine dynamics are often included in high fidelity rotorcraft simulations, it is quite common to exclude these dynamics when investigating low amplitude maneuvers. The RPM governing system on a helicopter will keep RPM nearly constant thus decoupling engine dynamics from the helicopter flight dynamics. This is a common approximation. For example, the CAA study on turbulence around off-shore oil platforms also used a constant RPM simulation model.
5. Advanced Wake Models: The Pitt-Peters inflow model has limitations but is suitable for this application. For example, the GENHEL simulation model normally uses Pitt-Peters or other simple finite state inflow models. The GENHEL code is used for flight dynamics analyses by both Sikorsky Aircraft and the U.S. Army Aero Flight Dynamics Directorate research lab. Flight dynamics models used in helicopter flight trainers, which are used by commercial and military pilots to train on emergency procedures and other flight operations, also use the Pitt-Peters inflow model.

**Dr. Corke’s claim that the model needs to include fully-coupled solutions of the urban airwake and rotor wake is *incorrect and impractical* for this study.** Dr. Corke backed up this claim using a quote from a 2007 AHS Forum paper on which Dr. Horn was a co-author. While this made for dramatic impact at the hearing, Dr. Corke failed to emphasize an important qualifying phrase in the quote. The phrase “when close to a solid structure” is very significant. The rotor wake can *in some cases* significantly alter the flow over a wake inducing structures upstream of the aircraft *if* the rotor is in close proximity to the structure. For example, the Navy has noted discrepancies in their one-way coupled simulations for helicopters operating over the landing spot on a destroyer, where the rotor is within in one rotor diameter distance to the structure (e.g. less than 50 to 60 ft for a typical helicopter used in naval operations). In this case, the closest major wake producing structure, Olympia Tower, is over 320 ft away from the center of the helipad. The elevator building on CMH is a little over 100 ft away from the

heliport, but it is relatively small and oriented obliquely to the helipad. It does not have a wall normal to its line of sight to the helicopter as would be seen behind a hangar on a destroyer. This small structure is not likely to generate important coupling effects.

Dr. Corke correctly acknowledged that fully coupled (or two-way coupled) solutions are very computationally expensive. The inclusion of coupling effects in this model would increase the cost and time required to perform the investigation many orders of magnitude. There is no guarantee that the calculations would even be possible. The research project would effectively become a high-risk multi-year research program. Dr. Corke and Dr. Veillette make other comments that suggest increasing the complexity and the scope of the analysis. Their suggested requirements as a whole would result in an analysis that is not only very costly but probably not even possible using the best computer technology that is available today.

**Dr. Corke claims that the Control Equivalent Turbulence Model cannot be used to model turbulence. This claim is counter to the claims of the world's leading experts on rotorcraft flight dynamics.** The CETI turbulence model was applied in this study to account for atmospheric turbulence effects that were underpredicted (not modeled) by the CFD airwake data. It is true that turbulence due to vortex shedding from buildings “are not random” as stated in Dr. Corke’s presentation, in that velocity fluctuations at a point in space are correlated with neighboring points. These correlations are present in the CFD airwake data, however. In the field of flight simulation, atmospheric turbulence effects, which the CETI model is used to represent in our study, are often modeled using similar random processes. The CETI model was developed by the research group of Dr. Mark Tischler, the Chief Scientist at the U.S. Army Aero Flight Dynamics Directorate (AFDD) at NASA Ames Research Center. Dr. Tischler is one of the world’s leading experts on rotorcraft flight dynamics and control. The CETI model was designed as a generic turbulence model valid for use in any simulation model of conventional helicopters, hence its application in our study. It was designed to capture the pertinent effects of ambient or airwake turbulence on helicopter handling qualities, and has been proven by fully instrumented flight tests.

**Dr. Corke’s method for defining error bounds on the helicopter flight dynamics model has no precedent in the field of helicopter simulation and flight dynamics.** In our collective 60+ man years of experience in rotorcraft flight simulation, Dr. Corke’s method to define error bounds on a rotorcraft simulation model have not been used. There are two main reasons (enumerated below) that his approach is not an appropriate method for defining error bounds on a flight simulation model.

**1. Dr. Corke used off-axis responses and long term open-loop responses to define error bounds, which is not standard practice in the field of helicopter simulation.** Dr. Corke’s initial error analysis used the doublet responses shown in Figures 5.3-1 to 5.3-8. The error bounds on aircraft attitude were defined using the largest error over the course of the time histories. Many of the error bounds were based on “off-axis responses”. The off-axis response is the unintended response to pilot control input, e.g. the aircraft pitch response following a lateral (or roll) control input. Even the most sophisticated rotorcraft simulations in the world do not capture off-axis response with complete accuracy. Furthermore, off-axis response is usually smaller in magnitude than the on-axis response and often appears to the pilot as a small disturbance for which the pilot intuitively compensates. Rotorcraft flight simulators are not

required to match the off-axis response with high accuracy. The FAA advisory circular on helicopter simulator qualification, AC120-63, does not have any quantitative requirements on the off-axis response. AC120-63 simply requires that the “off axis response shows the correct trend.” The relative importance of off-axis response was discussed in our report on page 52. It is possible that Dr. Corke was not aware of which responses are “on-axis” and which are “off-axis”, since at one point in his presentation he incorrectly indicated that longitudinal cyclic is controlled using left and right motion of the cyclic stick (in fact longitudinal cyclic is controlled using fore and aft stick inputs).

Dr. Corke assigned particularly large error bounds to the aircraft heading. The heading error bounds were based on the heading response to lateral and longitudinal doublets in hover (i.e. using off-axis responses). Furthermore he used the heading value at the very end of the time history. It is important to understand that even the most sophisticated rotorcraft simulation models in the world will exhibit significant error when simulating long term *open-loop* responses. The term “open-loop” response refers to flights where the pilot is *not* making continuous control adjustments to follow a desired trajectory. In the doublet input, the pilot applies a fixed input and lets the aircraft respond while holding the controls fixed. A helicopter in low speed and hover does not have a tendency to return to equilibrium following a control input. The helicopter will move away from its original equilibrium and any errors between simulation and flight test data will tend to grow steadily with time. This was discussed in our report on page 52. It is important to note that the final results of the study are based on *closed-loop* response of the simulated aircraft. The pilot model is controlling the aircraft to follow a desired trajectory. As such errors will *not* grow steadily in time. Any long term dynamic modes are stabilized by the pilot. As long as the *short term* on-axis response to pilot inputs (i.e. the response in the first 3 to 5 seconds following the pilot input) are accurate, the model can be expected to provide reasonable estimates of aircraft response.

**2. Dr. Corke’s method for defining error bounds from the approach and departure maneuvers is invalid.** Dr. Corke defined some of his error bounds based on the results shown in Figures 5.4-9, 5.4-10, 5.4-13, 5.4-14. These graphs show comparisons of the helicopter cyclic and attitude response in simulation and flight tests during an extended approach and departure maneuver. During these maneuvers, the helicopter is experiencing turbulence. As was clearly stated on page 62 of the report, it is not realistic to expect turbulence disturbances in the simulation to be in phase with those observed in flight test. Even if one were to develop a perfect model of the flow field, there is no way to ensure the simulated wind gusts will be synchronized with those observed in flight. We can only hope to produce disturbances that are statistically similar (i.e. similar magnitude and frequency of perturbations).

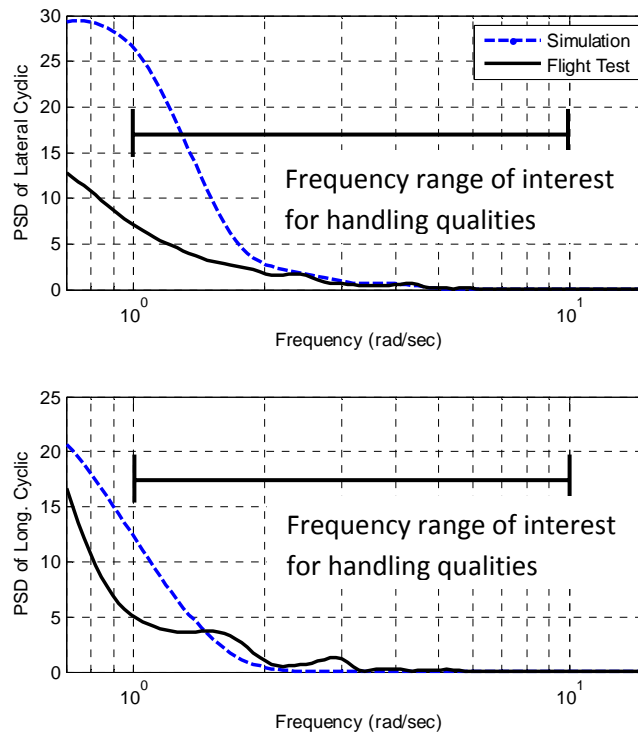
In spite of this, Dr. Corke proceeded to define error bounds by selecting the time interval with the largest discrepancy in attitude and control deflections. This is not an accepted method of validating a flight dynamics turbulence model.

To evaluate the simulation model’s accuracy and conservatism in predicting pilot control activity we draw from the methods presented in the following paper:

Lusardi, J. A., Tischler, M. B., Blanken, C. L., and Labows, S. J., "Empirically Derived Helicopter Response Model and Control System Requirements for Flight in Turbulence," *Journal of the American Helicopter Society*, Vol. 49, No.3, July 2004, pp.340-349.

By transforming the time history data into the frequency domain, one can compare the autospectra or power spectral density of the control signals. This provides a measure of the magnitude of fluctuations at different frequencies.

The figure below shows comparison of the power spectral density of the lateral cyclic and longitudinal cyclic input signals for flight test #14. This simulation case includes: the flight dynamics model, the pilot model, the CETI turbulence model, and the airwake model for case S14. Thus, it represents a complete end-to-end validation case. The frequency range of 1 to 10 rad/sec is known to be the most important frequency range for handling qualities. The results show that the simulation generally tends to significantly *over-predict* the magnitude of control activity in the frequency range of interest during the approach. This supports our claim that the analysis is *conservative*.



Another way to assess the accuracy of the overall model is to analyze simple statistical measures that summarize the attitude and control fluctuations over the course of the entire maneuver. Simply comparing the difference between peak-to-peak variations in controls and attitude and controls (i.e. the difference between the maximum and minimum attitude and control excursions) provides a measure of how well the model predicts control margins and vehicle upsets. This is summarized in the table below. The following table shows the root mean square of the attitude and control fluctuations, which

measures the average magnitude of the disturbances. The results again indicate that the overall model is a conservative predictor of attitude and control excursion when the helicopter is operating in the turbulence.

	Peak-to-peak variation in roll attitude (deg)	Peak-to-peak variation in pitch attitude (deg)	Peak-to-peak variation in lateral cyclic (%)	Peak-to-peak variation in longitudinal cyclic (%)
Simulation	15.6	23.3	24.2	22.3
Flight Test	10.4	16.4	14.9	22.2

	RMS variation in roll attitude (deg)	RMS variation in pitch attitude (deg)	RMS variation in lateral cyclic (%)	RMS variation in longitudinal cyclic (%)
Simulation	2.0	3.7	3.6	5.3
Flight Test	1.4	3.0	3.4	4.1

**Dr. Veillette’s assertion that the simulations were performed in “ideal conditions” is misleading.** Note that the simulations were run with the maximum allowable wind speeds as defined by the operating limits of the heliport. This is hardly an ideal condition. Furthermore, the pilot model was structured to use only attitude and velocity feedback, which can be viewed as being representative of information obtained through visual cues. Human pilots also sense and react to rate and acceleration (vestibular) cues, which provides additional anticipation (“lead” to the feedback control provided by the pilot model). Anticipation or lead in feedback control is well known to provide additional stability, thus the pilot model used in our study does not represent the control strategy of an “optimal” or “ideal” pilot.

**Dr. Veillette provided a misrepresentation of U.S. Navy Dynamic Interface testing.** The quotes from the presentation slide are:

“Navy learned operational limits the hard way. Lack of an accident does not indicate or predict safety.”

From the transcript of the hearing:

“Well, let me tell you, having been a former military and that this approach of test, test, test, oops, is a costly way to learn what your limits should be.”

This interpretation implies that the United State Navy judges safety solely on whether or not they experience a mishap. It also implies that operating envelopes are continuously expanded until a helicopter crash, at which point operational limits are defined. Of course nothing could be further from the case. The dynamic interface testing program was specifically developed to reduce accidents, and has successfully achieved this goal. This is why all new helicopters, ships, and landing platforms must

undergo this testing. Dynamic interface testing is a highly controlled and incremental test procedure. At each test point, pilots provide a numerical rating of work load and safety. The threshold for defining an operational limit has a substantial safety margin, so that as the envelope is expanded, limits are set well before the pilots reach a condition that would seriously jeopardize safety. Pilots also provide detailed comments on the factors that drive the workload for the given conditions. This adds to a database of knowledge so that test pilots know what hazards to expect in future tests. While there have certainly been accidents of fleet helicopters operating in the dynamic interface, no accidents are known to have actually occurred during Dynamic Interface Testing (i.e. the formal testing used to define operational limits).

Flight tests at the heliport should also be conducted in a highly controlled manner. As recommended on page 91 of the report: “The tests should have some formal system for evaluating pilot opinion and assessing safety (e.g. a pilot rating system as used in dynamic interface testing or handling qualities analysis).” Of course the tests would also be conducted with highly competent and well rested pilots.

**The analyses required by Dr. Corke and Dr. Veillette are prohibitively expensive. As a whole they are probably not even feasible with best computing technologies available.** The following is a summary of the required analyses that Dr. Corke and Dr. Veillette have suggested as being essential for proper assessment of urban airwake effects at the heliport:

1. Viscous, large-eddy CFD simulations of the Streeterville area.
2. Run CFD wind cases for 16 different wind directions (this was recommended in Dr. Corke’s review of the RWDI study).
3. Develop a flight simulation model that includes: aero-elastic rotor blades, dynamic stall, transonic flow effects, wake model with rotor-to-rotor interactions, and blade vortex interactions.
4. The model described above would need to be validated against flight test data and show precise correlation with both off-axis and on-axis responses over long term maneuvers.
5. The model would need to include fully-coupled solutions of the urban airwake and the helicopter rotor wake.
6. According to Dr. Veillette’s comments, the simulation runs would have to consider at least ten different variables in addition to wind direction and approach path. These variables included time-varying wind, non-optimal (i.e. fatigued) pilot, pilots working from inaccurate wind conditions, deviations from the approach trajectories, equipment problems, ambient temperatures, and different operating conditions. In addition, the simulations would have to consider takeoffs and aborted approaches. The testing matrix would be enormous. Assuming only three variations for each of the added variables, plus 16 wind conditions and 3 different approach paths, this would result in over 2.8 million permutations in test conditions.
7. Dr. Veillette also implied that visibility should be considered. This yet another variable to include in this study. However, the effects of visibility (or what is termed “Degraded Visual Environment”) could only be evaluated using piloted simulations in a high fidelity simulator (or through flight tests).

An analysis of this scale would not only be extremely expensive, it would probably be impossible. Items #3 and #5 would require a fully coupled Computational Structural Dynamics (CSD), Computational Fluid Dynamics (CFD), and Flight Dynamics Simulation. Such models do not currently exist. Coupled CSD/CFD is a matter of ongoing research. The 2011 American Helicopter Society Annual Forum had an entire technical session devoted to research on coupled CSD/CFD. The computer software required to perform these analyses can take weeks to analyze a single short term maneuver, and in these cases the CFD domain is restricted to a region in the immediate vicinity of the helicopter. If the urban airwake CFD solution is coupled into the solution, the computational domain would become much larger and computation times would increase by orders of magnitude. Item #7 requires real-time piloted simulations, which are not feasible for fully coupled simulations (or any simulation that requires concurrent CFD calculations). Even excluding piloted simulations, the test matrix requested by Dr. Veillette in item #6 would be impossible to achieve with such complex models and would be very time consuming using a simple dynamic model.

In summary, Dr. Corke and Dr. Veillette are steering toward a standard of analysis that is completely impractical. Even a small subset of the analyses they propose would result in a multi-year, multi-million dollar research program. We feel that the analytical methods that we used are consistent with currently accepted practices of the helicopter handling qualities community, representative of how comparable flight environments are simulated, and of a scope appropriate for the present review process. It is unlikely a more extensive computational research program would yield more accurate or more relevant data than a well-defined and controlled flight test program.