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Federal Aviation Administration

NSP GB

National Simulator Program
FSTD Qualification Guidance Bulletin

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National Simulator Program Guidance Bulletin

An NSP GB contains valuable information for FSTD sponsors that should help them meet certain administrative, regulatory, or operational requirements with relatively low urgency or impact on safety.

Subject: Realistic Gusting Crosswind Profiles for Flight Simulation Training Device (FSTD) Qualification.

Purpose: Provide baseline gusting crosswind models to FSTD sponsors for use as an acceptable means of compliance for Title 14 of the Code of Federal Regulations (14 CFR) part 60[1].

Background: In November 2013, the Federal Aviation Administration (FAA) published a final rule that amended air carrier training requirements to include takeoff and landing in a crosswind with gusts. These changes were made in part to address National Transportation Safety Board (NTSB) safety recommendations as a result of the Continental flight 1404 accident that occurred in Denver, Colorado in 2008[2.] Furthermore, as a result of the accident investigation, it was noted that some existing simulators do not have the capability to replicate surface gusting crosswinds, nor was there an existing minimum simulator qualification requirement to do so. As a result of the accident investigation, the NTSB issued an additional safety recommendation for the FAA to gather "data to develop realistic, gusty crosswind profiles for use in pilot simulator training programs".[3] In response to this safety recommendation and to support new air carrier training requirements, the FAA amended part 60 to require implementation of realistic gusting crosswind profiles and provide a statement of compliance describing the source data used to construct gusting crosswind profiles. This requirement will be mandatory for all Level C and D FSTDs initially qualified after the rule change becomes effective, and for previously qualified FSTDs that are specifically used to meet this training requirement.

[1] 14 CFR Part 60, Table A1A (General Simulator Requirements), Section 2.d.3.
[2] Runway Side Excursion During Attempted Takeoff in Strong and Gusty Crosswind Conditions, Continental Flight 1404, December 20, 2008, NTSB Final Report, NTSB/AAR-10/04
[3] NTSB Safety Recommendation #A-10-110.

Revision	Description of Change	Effective Date
0	Original Draft.	04/11/2016

Wind Models

To support part 60 requirements for realistic gusting crosswinds, the FAA constructed two wind gust models developed from wind estimates computed by the NTSB based upon parameters extracted from the Continental flight 1404 flight data recorder.[4] One of the gust models was developed using a "sum-of-sines" solution to match both the wind magnitude and the wind direction experienced by the accident aircraft. The second model was developed using a simplified linear estimation of the wind magnitude and direction experienced by the accident aircraft. This linear model was developed as an alternative solution that may be easier to implement on a typical FSTD.

The FAA implemented these wind gust models on a Boeing B737-800 Level D simulator and conducted testing using pilots with operations experience in transport category aircraft. This testing replicated the conditions of the Continental 1404 accident. The pilots assessed the subjective realism of the wind gust models, as well as the relative difficulty of the maneuver as compared to steady state crosswind conditions. The results of the experiment showed that both wind gust models were subjectively realistic and beneficial to training.

While the FAA experiment tuned the wind models to match the Continental 1404 accident conditions, the wind models provided in Attachment 1 of this guidance bulletin have been adjusted to remove the steady state bias terms to allow for use on any runway heading as an increment to the current steady state wind conditions in the simulator. Additional tuning of the model is recommended to address pilot subjective assessment, the crosswind capabilities of the particular aircraft, and any limitations on the simulator's aerodynamic and ground models.

Part 60 Qualification of Gusting Crosswind Profiles

To meet part 60 requirements, the baseline wind gust models provided in Attachment 1 of this guidance bulletin may be used as an acceptable data source to develop realistic gusting crosswind profiles for FSTD qualification. Additional tuning and implementation guidelines are provided in Attachment 1. As described in the part 60 requirement, FSTD sponsors may develop other wind gust models for FSTD qualification.

Contact: Questions or comments regarding this guidance bulletin can be directed to the National Simulator Program, AFS-205, at (404) 474-5620.

[4] Crider, D.A., "Determining Ground Winds for Gear-on-the-Ground Accidents Using FDR Data," *2011 AIAA Modeling and Simulation Technologies Conference and Exhibit,* AIAA-2011-6699, Portland, Oregon, 2011.

<u>Attachment 1 – Wind Gust Models</u>

Continuous Gust Model

Model 1, hereafter referred to as the “continuous model”, was developed through matching Continental 1404 accident data with a sum-of-sines fit for both wind magnitude and wind direction. The results are two equations (one for wind magnitude and one for wind direction) composed of nine individual sine/cosine frequency components derived from the following equations with steady state components removed.

Gust model direction = $[A_1*\text{cosine}(f_1*t)+B_1*\text{sine}(f_1*t)+ A_2*\text{cosine}(f_2*t)+B_2*\text{sine}(f_2*t)+\ldots +A_n*\text{cosine}(f_n*t)+B_n*\text{sine}(f_n*t)]$

Gust model magnitude = $[C_1*\text{cosine}(f_1*t)+D_1*\text{sine}(f_1*t)+ C_2*\text{cosine}(f_2*t)+D_2*\text{sine}(f_2*t)+\ldots +C_n*\text{cosine}(f_n*t)+D_n*\text{sine}(f_n*t)]$

Table 1 below provides coefficients and frequencies for each of the terms in the equations provided above.

Table 1: Coefficients for Sine/Cosine Frequency Components – Continuous Gust Model

N	Model direction cosine coefficients (A_n)	Model direction sine coefficients (B_n)	Model magnitude cosine coefficients (C_n)	Model magnitude sine coefficients (D_n)	Model frequencies (rad/sec) (f_n)
1	**5.03**	**-1.08**	**-0.95**	**-0.69**	**0.68**
2	**5.62**	**8.59**	**-4.02**	**-1.75**	**1.36**
3	**7**	**-1.76**	**-4.5**	**2.05**	**2.04**
4	**2.68**	**-0.57**	**-1.5**	**0.3**	**2.72**
5	**2.19**	**-1.33**	**-1.03**	**1.29**	**3.4**
6	**0.87**	**-0.071**	**-0.14**	**-0.33**	**4.08**
7	**1.17**	**-2.11**	**-0.59**	**1.44**	**4.75**
8	**0.11**	**-1.84**	**0.069**	**1.04**	**5.43**
9	**0.056**	**-1.36**	**0.21**	**0.73**	**6.11**

Figure 1 and Figure 2 below are the output of the described wind direction and wind magnitude models over plotted with the unbiased NTSB data from the Continental 1404 accident.

Figure 1: Continuous Gust Model Magnitude

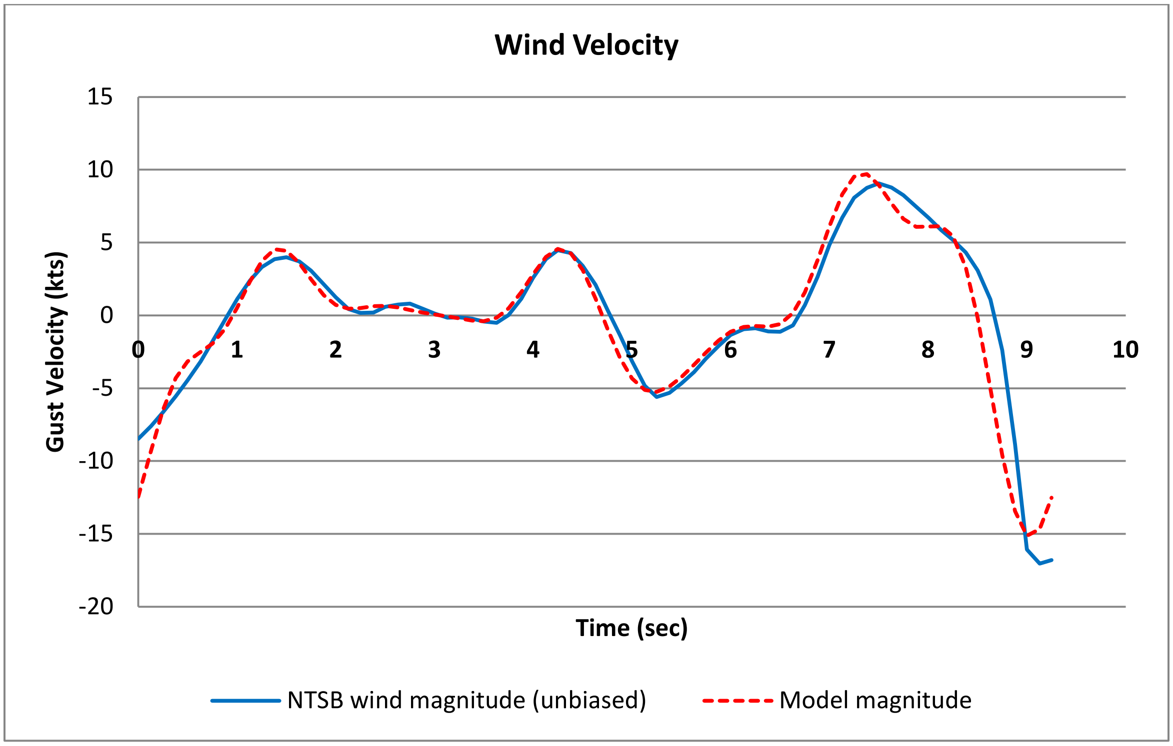
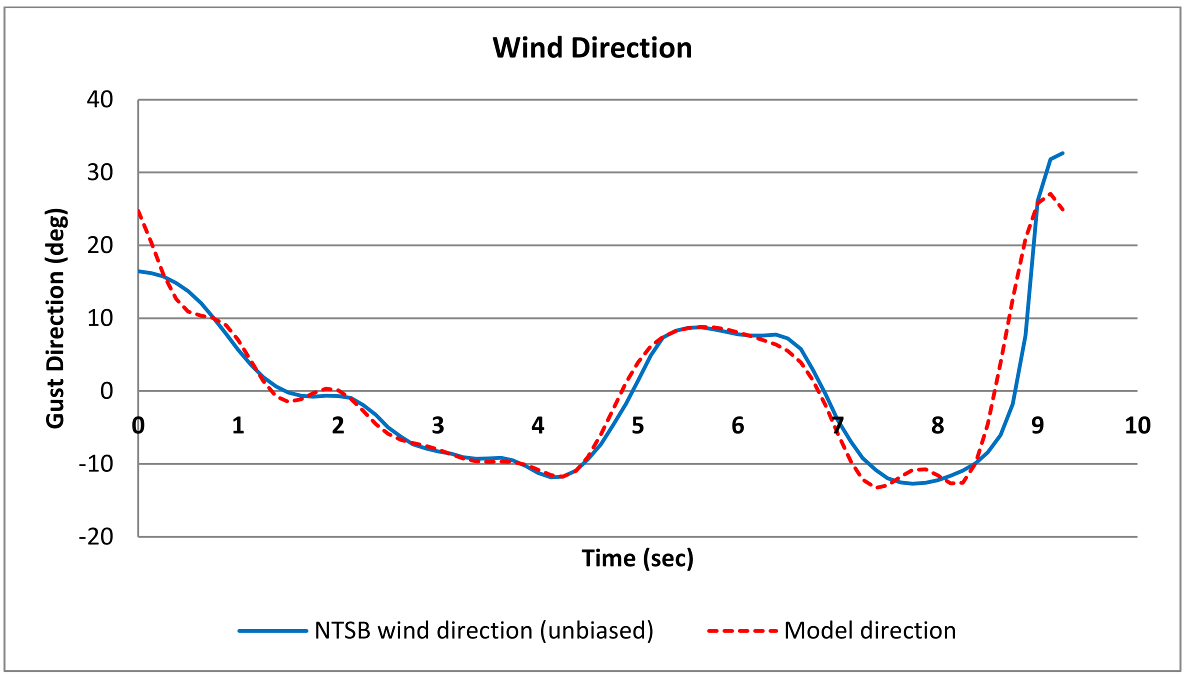


Figure 2: Continuous Gust Model Direction



Linear Gust Model

Model 2, hereafter referred to as the "linear model", was developed as an alternate solution that may be more straightforward to implement in a typical simulator. Like the continuous gust model, this model was also developed using the accident data from Continental flight 1404, but a linear solution was derived that may simplify its implementation.

To implement the linear model, the tables below provide the breakpoints for both the gust model velocity (Table 2) and the gust model direction (Table 3). Additionally, the slopes of the lines are provided for each segment of the model (wind rate and direction rate).

Table 2: Breakpoints for Linear Gust Model (Velocity)

model time (sec)	model_vel (kts)	Velocity Rate (kts/sec)
0	0	
1.0	0	0
2.5	10	6.666
3.25	5	-6.666
4.25	5	0
5.0	10	6.666
6.5	0	-6.666
8.75	15	6.666
11.0	0	-6.666

Table 3: Breakpoints for Linear Gust Model (Direction)

model time (sec)	model_direction (deg)	Direction Rate (deg/sec)
0	0	
1.0	0	0
5.0	-30	-7.5
6.5	-10	13.333
7.5	-10	0
8.5	-30	13.333
9.5	-30	0
11.0	0	20.0

This linear gust model is represented below in a graphical format in Figure 3 and Figure 4 below as compared to the CO 1404 accident data:

Figure 3: Linear Gust Model Magnitude

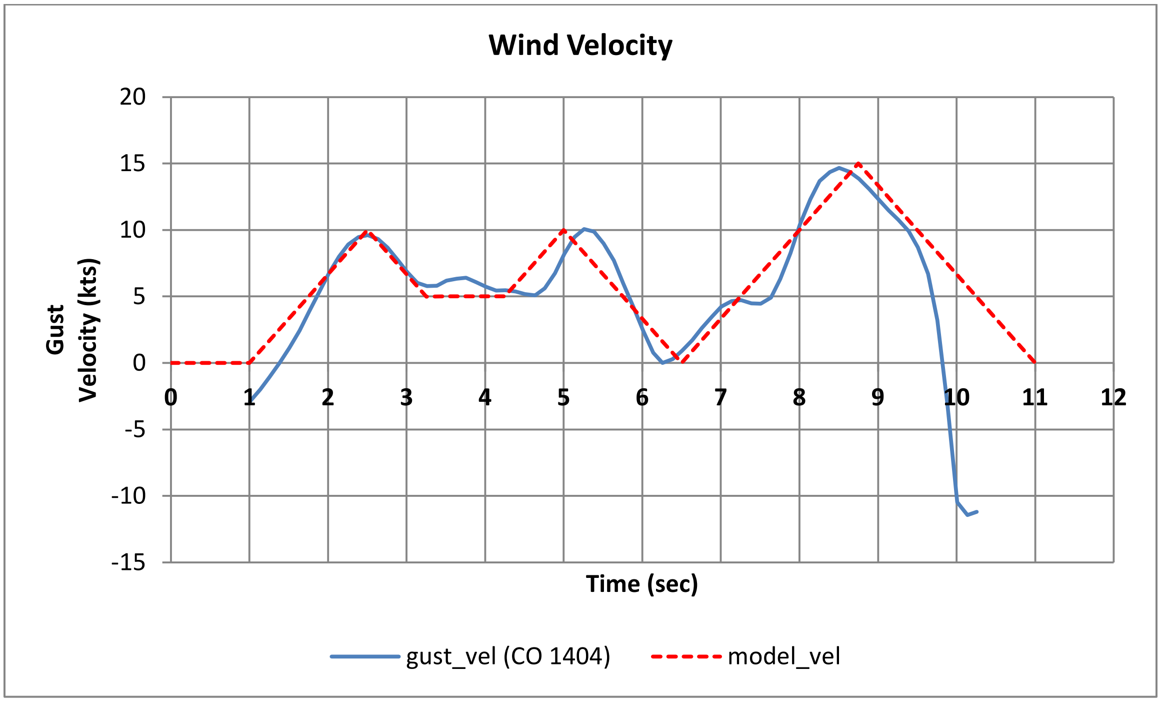
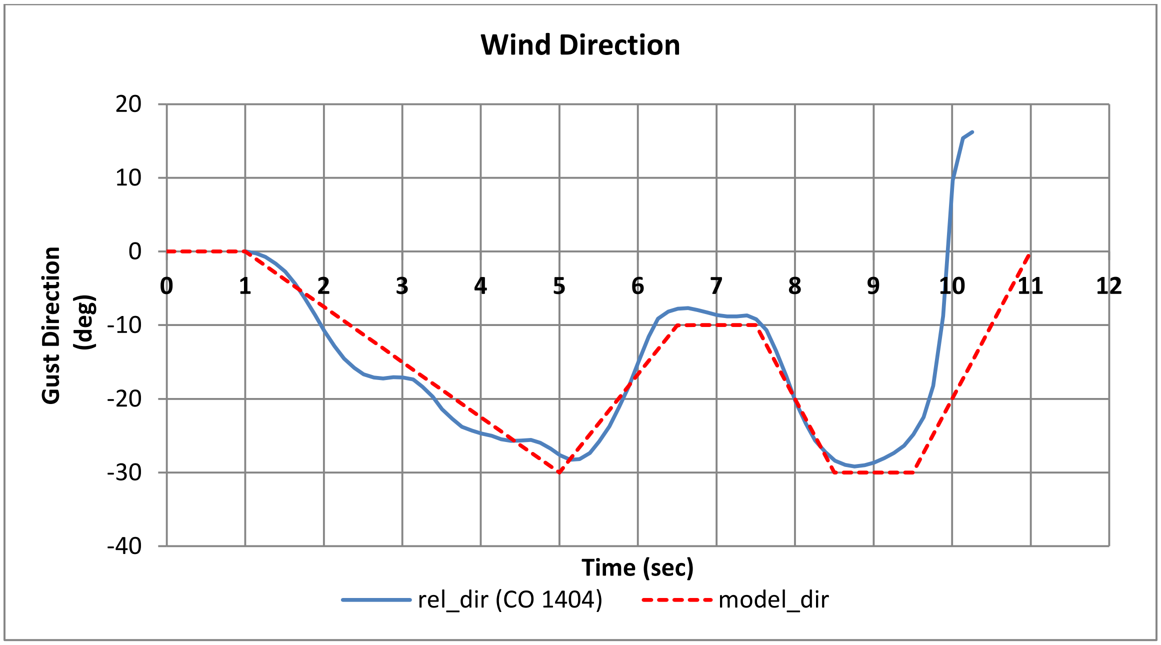


Figure 4: Linear Gust Model Direction



Implementation and Tuning Considerations

- The continuous wind gust model is a periodic sinusoidal function with its bias terms removed. As a result, the output of this model may be summed into the current steady state wind velocity and direction to add gust components that are incremental to the steady state wind condition. Because the gust model can start in a non-zero condition, it may require additional filtering to gradually ramp it in once triggered.
- The linear wind gust model is a non-periodic function that covers eleven seconds of gust data. As a result, if continuous gusty conditions are required, the model must be set up to repeat at eleven second intervals or at another duty cycle as desired for training purposes. Like the continuous wind gust model, this model has also had its bias terms removed and can be summed into the current steady state wind conditions programmed on the instructor operating station (IOS).
- Before implementing in a training environment, these gust models should be tuned for the particular aircraft being simulated and intended training scenarios. The following issues should be considered in the tuning process:
    - A subject matter expert (SME) pilot should be used to provide assistance in tuning and evaluating the gust models for takeoff and landing training tasks.
    - Because the wind magnitude and direction rates of change in the gust models are based upon objective data, any scaling of these terms may affect the realism of the wind gust in training. To adjust the difficulty of the wind gust training scenarios, it is recommended that the steady state wind conditions be adjusted to achieve the desired maximum crosswind components after the wind gusts are summed in.
    - When tuning the wind gusts, the maximum crosswind capabilities of the aircraft must be considered. While briefly exceeding the aircraft's maximum demonstrated crosswind component after the gust model has been activated may provide some training value, the steady state wind conditions at the start of the scenario should not exceed what is acceptable for takeoff or landing in an operational environment.
- Additionally, the capabilities of the FSTD and associated aerodynamic and ground models must be considered. The FSTD sponsor should coordinate with the FSTD manufacturer and/or data provider to ensure the wind gust models do not exceed the capabilities of the FSTD.