Aircraft Simulation – Predicting when a runway is too rough.

By Michael Gerardi

When you sit and think about it, the only real interface a passenger has with the takeoff or landing experience is the ride quality – will it be bumpy or will it be smooth? In most cases, the operation is conducted and nothing is said; it must have been a smooth ride. However, if the pavement produces poor ride quality, pilots and passengers typically speak up. The problem is that there are no official criteria which say what is *too rough* and what is *acceptable*. It remains a fairly subjective process.

APR uses aircraft simulation to predict how an aircraft will respond to the measured pavement profile. The aircraft model responds to the variation in the measured profile and reports that response in accelerations (g's) and dynamic loading onto the pavement.

So, what do we consider too rough? To answer that question, APR uses a study published in Volume III of the Shock and Vibration Handbook, Chapter 44 "Effects of Shock and Vibration on Man" by D. E. Goldman and H. E. Von Gierke. In essence, this study placed human subjects on a shaker table exposing them to a range of vibrations at various frequencies. The experimenters asked the subjects when the vibrations were *perceptible*, when the vibrations became *uncomfortable* and when the vibrations became *unbearable*. This study found that .04g became the common point of when vibrations became *uncomfortable*.

From this study, APR began using +/-.40g as a threshold for identifying areas of roughness. A typical plotted simulation plots the accelerations predicted for two locations of the aircraft; the Pilot's Station, identified on the plot's upper Y-axis with PSA, and the aircraft's center of gravity, identified on the plot's middle Y-axis as CGA. Each of these acceleration oscillations are banded with two red lines denoting positive and negative .40g. When the predicted accelerations reach or exceed those red bands, we consider the area to generate excessive response. Depending upon how great the predicted acceleration was – in terms of duration and peak acceleration, we will classify the response as either mild, moderate or significant.

Figure 1 illustrates the results of a Boeing 737-800 Takeoff Simulation on a smooth runway. Note the +/-.40g band is not violated at either the pilot's station (upper band) or at the aircraft's center of gravity (lower band).

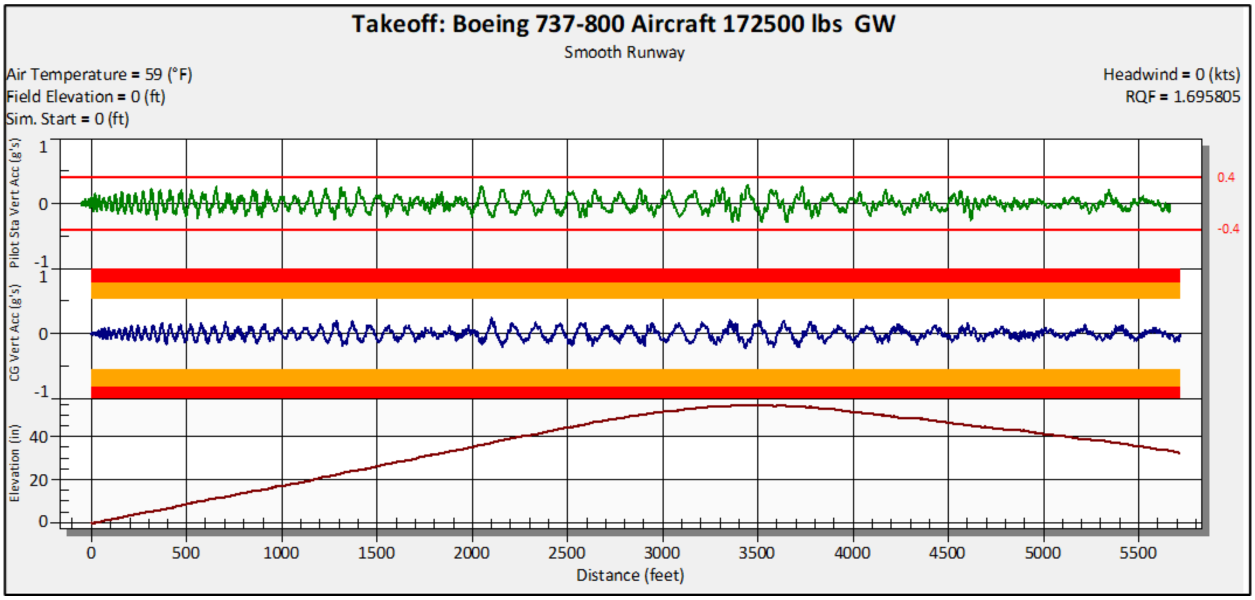

Figure 1. Takeoff simulation on a relatively smooth runway.

All accelerations are not equal. That's to say that it is much more common to experience higher accelerations in the front of the aircraft than it is over the aircraft's center of gravity. Because the Pilot's Station is at the end of a long arm (distance from the main gear about which the aircraft pivots as it pitches up and down) that section of the aircraft will generally experience a rougher ride. Now, if the aircraft's center of gravity is predicted to experience moderate levels of response, those responses will have more significance when rating the level of roughness for that section of pavement than if only the pilot's station was predicted to generate response.

Figure 2 illustrates a takeoff simulation on a runway that contains multiple event roughness.

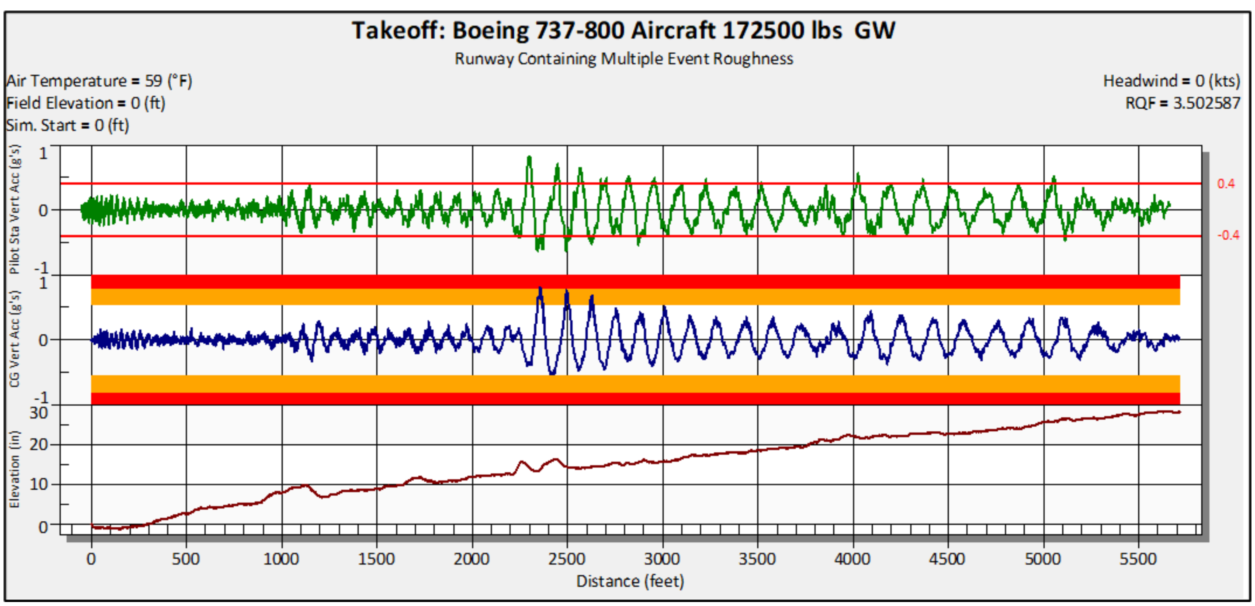

Figure 2. Takeoff simulation on a runway with multiple event roughness.