



Date: March 12, 2024

To: Aaron Sauer, Office of Aviation Safety

From: John O'Callaghan, Office of Research and Engineering

Subject: Airplane performance plots during landing for CEN23LA403

Aaron:

This memorandum transmits plots of several airplane performance parameters for IAI 1125 Westwind Astra N39TT during its landing roll at Chicago Executive Airport (KPWK) runway 16 on August 21, 2023 (NTSB accident #CEN23LA403). After landing, the pilot, perceiving that the brakes "were not grabbing," attempted a left turn to exit the runway onto the 45° taxiway D, which he thought provided additional stopping distance (see Reference 1). The airplane slid off the taxiway and came to rest in the grass adjacent to the runway, sustaining substantial damage. The two pilots, the only occupants of the airplane, were not injured. The performance calculations and plots presented here are based on Automatic Dependent Surveillance – Broadcast (ADS-B) data for the accident flight, reported weather at the time, and data available from Honeywell N1 Digital Electronic Engine Control (DEEC) devices installed on the airplane's engines. The airplane was not equipped with a Flight Data Recorder. The airplane was equipped with a Cockpit Voice Recorder, but this device did not contain any audio recorded during the accident flight.

Figure 5 compares the ground speed distance of the Astra during a landing roll for various combinations of airplane configuration and wheel braking friction coefficients, as computed using a simulation of the airplane that incorporates aerodynamic estimates of lift and drag from documents provided by Gulfstream, and engine thrust data provided by Honeywell. The results are compared with available ADS-B data for N39TT while the airplane is on the ground. Figure 5, the simulations, and ADS-B data are discussed further below.

For all the simulations, the flaps are at 40°, and no reverse thrust is used, consistent with evidence from a video of the landing. Based on the Honeywell DEEC data, the simulation uses an estimated forward thrust corresponding to an N1 of about 35%. An additional simulation is run with thrust corresponding to an N1 of 30% to determine

the sensitivity of the results to uncertainties in N1 (the Honeywell DEEC does not record exact N1 values, but only a range of possible values for N1).

At the time of the accident the runway was dry, and so the simulations use a dry-runway maximum available friction coefficient (μ) model obtained from the Engineering Sciences Data Unit (ESDU) Item 71026 (Reference 2), and an anti-skid system efficiency (η) of 80%, consistent with η values specified in FAA regulatory and guidance materials. The product of these parameters yields the wheel braking friction coefficient (μ_B) available to stop the airplane, as described below.

ADS-B data was obtained from both the Federal Aviation Administration (FAA) and ADS-B Exchange¹, as shown in Figures 1 - 4.

The ADS-B data file provided by the FAA includes:

- Time of the ADS-B messages in Universal Coordinated Time (UTC), at a frequency of approximately 1 report every second (1 Hz).
- Latitude, as determined by the airplane's Global Navigation Satellite System (GNSS) receiver, recorded to the nearest hundredth of an arc-second.
- GNSS longitude, recorded to the nearest hundredth of an arc-second.
- GNSS altitude, recorded to the nearest 25 feet (i.e., within an uncertainty of ± 12.5 ft.). The GNSS altitude is the height above the WGS84 ellipsoid. Altitude above mean sea level (MSL) is obtained by subtracting the height of the geoid above the ellipsoid from the GNSS height. In this case, MSL altitude = GNSS altitude + 113 ft. (at KPWK, the geoid is 113 ft. below the ellipsoid).
- Pressure altitude to the nearest 25 feet.
- Avionics-reported² GPS-based north and east velocities recorded to the nearest knot.
- Avionics-reported barometric-based rate of climb recorded to the nearest foot per second.

The recorded ADS-B positions defining N39TT's flight path during the last minute of the accident flight (as N39TT was descending through about 900 ft. MSL / 250 above ground level (AGL)) are plotted as north and east coordinates relative to the KPWK runway 16 threshold in Figure 1. The labeled points indicate the ADS-B time in HH:MM:SS Central Daylight Time (CDT).

¹ See <https://www.adsbexchange.com/>.

² Here "avionics-reported" indicates that the recorded speed values were computed by the airplane's avionics and broadcast over the ADS-B system, as opposed to being computed on the ground using the GNSS latitude and longitude coordinates broadcast by the airplane.

The ADS-B Exchange data was obtained by downloading a *Google Earth* .kml file from the ADS-B Exchange website, and extracting the following parameters from this file:

- Time of the ADS-B messages in Universal Coordinated Time (UTC).
- GNSS Latitude.
- GNSS longitude.
- Pressure altitude.

The ADS-B Exchange data is compared to the FAA ADS-B data in Figures 1-4. Note in Figure 5 that the FAA data ends while the airplane is still rolling down the runway at a speed of about 87 knots. The ADS-B Exchange data includes a few more points, and captures the position of the airplane at rest.

Although the FAA ADS-B data does not capture N39TT's ground roll all the way to the stop, it has the advantage of containing the ground speed reported by the airplane. This speed is very well-behaved and smooth. The ADS-B Exchange data captures the airplane at rest, but does not include the ground speed reported by the airplane itself. Consequently, the ground speed corresponding to the ADS-B Exchange data must be computed from the positions and times recorded in the data. The result is somewhat noisy, as shown in Figure 5. Further, the final ADS-B points are not evenly spaced in time, but include relatively large time gaps (up to 14 seconds) between points, and these gaps introduce uncertainty in the speed calculation. For example, Figure 2 (which plots the ADS-B data, converted into runway coordinates, vs. time) shows that N39TT was at its resting position at 13:12:35, and so its ground speed was zero at that time; however, the airplane could have reached the resting point some seconds before 13:12:35, and so it cannot be concluded that the ground speed just reached zero at 13:12:35.

Figures 3 and 4 present the recorded ADS-B pressure and geometric altitudes as a function of time (Figure 3) and of the runway x-axis coordinate (Figure 4). The runway x-axis originates at the threshold and extends down the centerline, and is labeled in Figures 4 and 5 as "distance from KPWK runway 16 threshold, feet." Figure 4 suggests that the airplane touched down a little more than 1,000 ft. from the threshold; in the simulations, it is assumed that the airplane has all three gear on the ground and the brakes are fully applied starting at 1,500 ft. from the threshold.

Figure 5 compares the ground speed vs. the runway x-coordinate obtained from the ADS-B data with the results of several simulations. The simulations differ in the assumed value of the anti-skid system efficiency (η) and in the position of the airbrakes (deployed or stowed). The value of η is varied simply as a way of adjusting the braking performance of the airplane, and has no relevance to the actual status of the anti-skid system on N39TT.

The braking force on the tires (F_B) is equal to the normal force on the braked tires (that is, the weight supported by the tires, or N) multiplied by μ_B :

$$F_B = (N)(\mu_B) \quad [1]$$

μ_B is the product of the maximum available friction coefficient (μ) and η :

$$\mu_B = (\mu)(\eta) \quad [2]$$

Combining Equations [1] and [2],

$$F_B = (N)(\mu)(\eta) \quad [3]$$

Figure 6 plots μ_B vs. ground speed for different combinations of μ and η . The green lines depict the dry-runway μ modeled in Reference 2 for 135 psi tires and $\eta = 0.8$. This is the value of η that is specified in 14 Code of Federal Regulations [CFR] 25.109(c) for modeling braking friction on wet runways. The different green lines in Figure 6 depict the range of the dry-runway μ evident in the friction data presented in Reference 2. Since KPWK runway 16 was dry at the time of the accident, the μ_B that N39TT could have been expected to attain lies in the range bounded by these green lines. The simulations assume the “average” dry-runway μ in Reference 2, and modify η to obtain different levels of μ_B .

As shown by the green lines in Figure 5, with the average μ and $\eta = 0.8$, the airplane decelerates at a much greater rate than that evidenced by the ADS-B data, whether or not the airbrakes are deployed. To match the ADS-B data while keeping μ at the same value, η has to be reduced to 0.4 (if the airbrakes are stowed) or to 0.2 (if the airbrakes are deployed). The μ_B resulting from these combinations of μ and η are plotted in Figure 6, and lie well below the range of possible dry-runway μ_B presented in Reference 2. The wet-runway μ_B modeled in 14 CFR 25.109(c), which is used in FAA guidance material (the Runway Condition Assessment Matrix, or RCAM) for computing stopping distances on wet runways, is plotted in Figure 6 for comparison.

The η of 0.4, which makes the airbrake-stowed simulation approximately match the ADS-B data, results in a μ_B about equal to the average wet-runway μ_B across the speed range (the dry-runway μ_B does not decrease as much with ground speed as the wet-runway μ_B does). The η of 0.2, which makes the airbrake-deployed simulation approximately match the ADS-B data, results in a μ_B about equal to the wet-runway μ_B at 140 knots, which is extremely improbable on a dry runway.

Given these considerations, the simulation results point to a braking reduction or loss of anti-skid efficiency during the accident landing roll (assuming full-braking efforts by the pilots immediately after touchdown). The magnitude of the deficiency required to match the ADS-B data depends on whether the airbrakes are stowed or deployed; however, it is unlikely that the simulations (by themselves) can help resolve whether

the airbrakes were deployed or not. If the reduced deceleration evidenced by the ADS-B data could be explained simply by the airbrakes being stowed (while keeping μ_B close to its expected dry-runway value), that could help to inform a conclusion that the airbrakes were indeed stowed. However, the simulations indicate that even when the airbrakes are deployed, μ_B must be reduced by half from its expected value to match the ADS-B data. Consequently, the lack of deceleration during the accident cannot be explained solely by postulating that the airbrakes were stowed, and the simulation results (by themselves) cannot be used to determine the actual airbrake position.

I hope these results are useful to the investigation. Please let me know if you would like to discuss the contents of this memorandum further.

Regards,

John O'Callaghan
National Resource Specialist – Aircraft Performance

References

1. National Transportation Safety Board, Office of Aviation Safety, *Preliminary Report: Israel Aircraft Industries 1125 Westwind Astra, N39TT, Wheeling, Illinois, August 21, 2023* (NTSB accident # CEN23LA403). (Available through the NTSB CAROL search tool at <https://data.nts.gov/carol-main-public/landing-page>).
2. Engineering Science Data Unit (ESDU) Item 71026, *Frictional and Retarding Forces on Aircraft Tyres, Part II: estimation of braking force (friction data updated - 1981), with Amendments A and B*, August 1981. Sponsored by the Royal Aeronautical Society. For ESDU items see <https://ihsmarkit.com/index.html>.

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Plan view of available ADS-B data

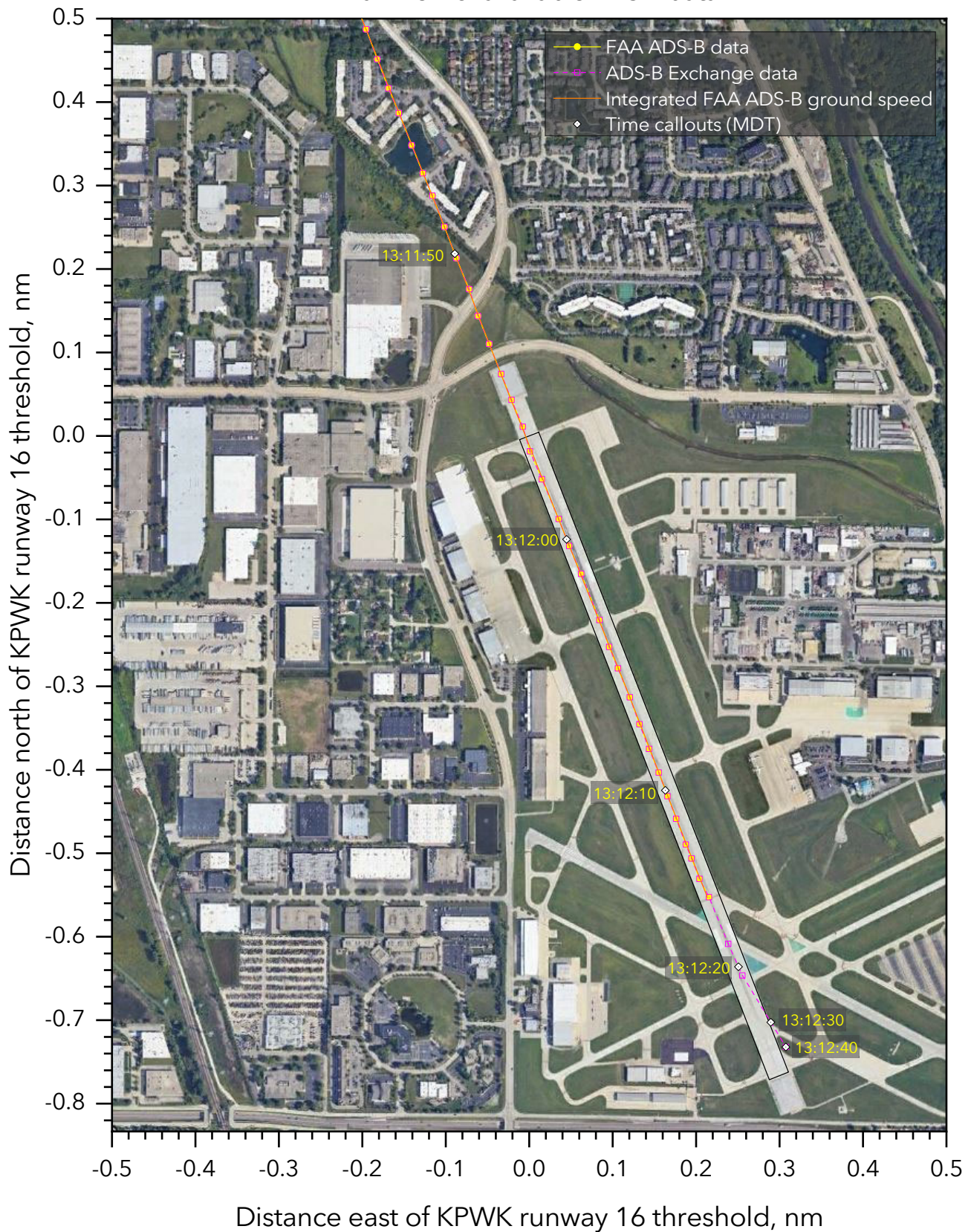


Figure 1.

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ADS-B runway coordinates vs. time

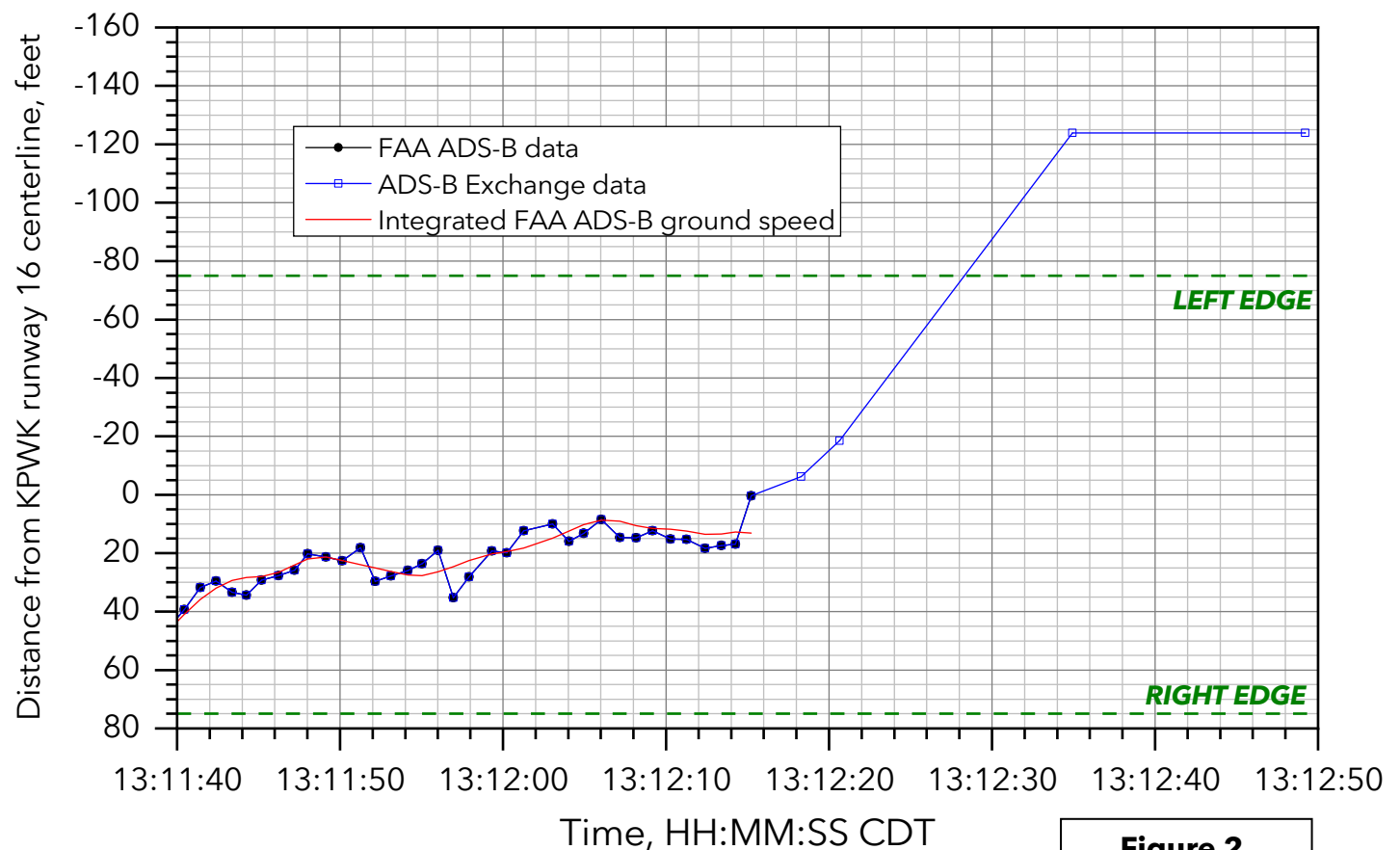
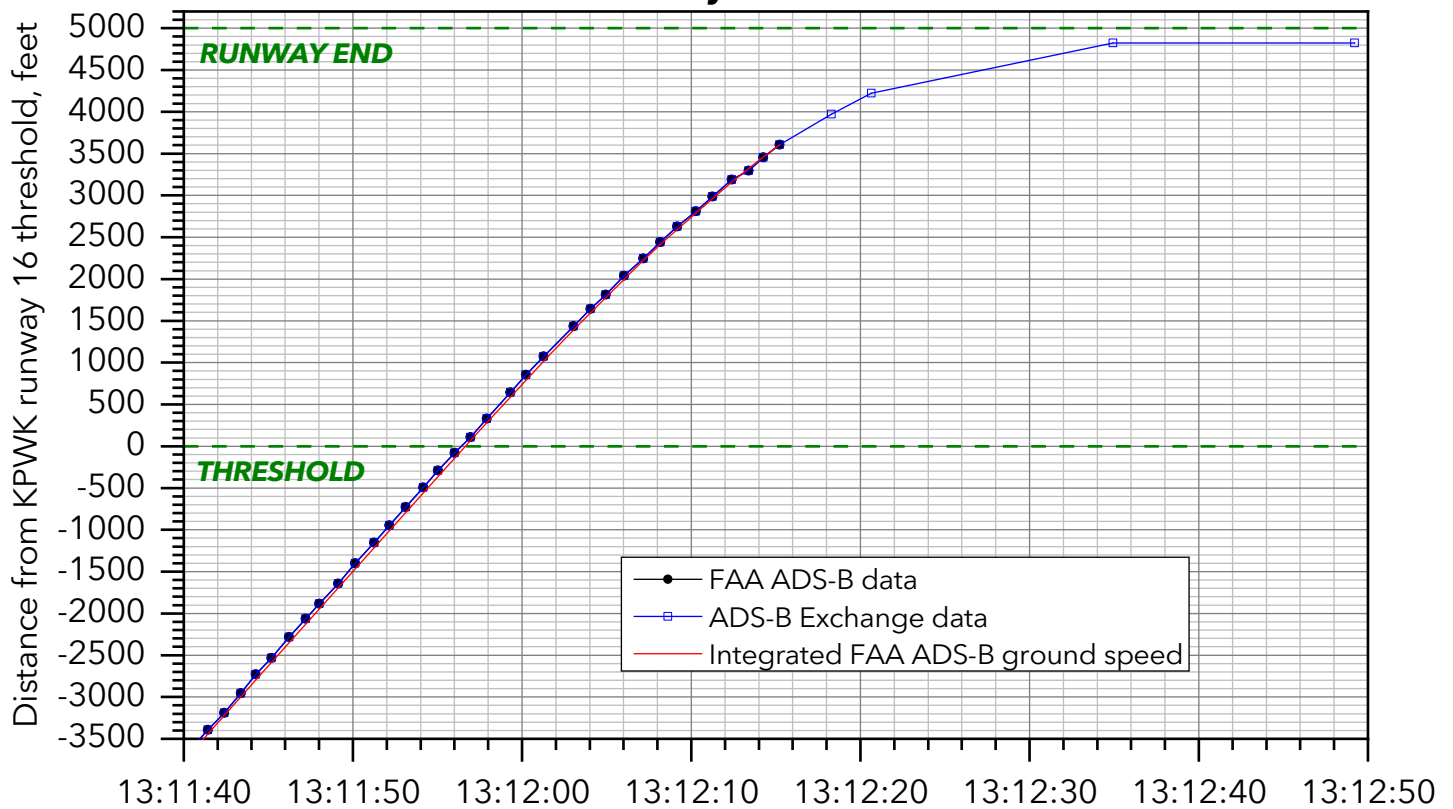


Figure 2.

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Altitude vs. time and distance

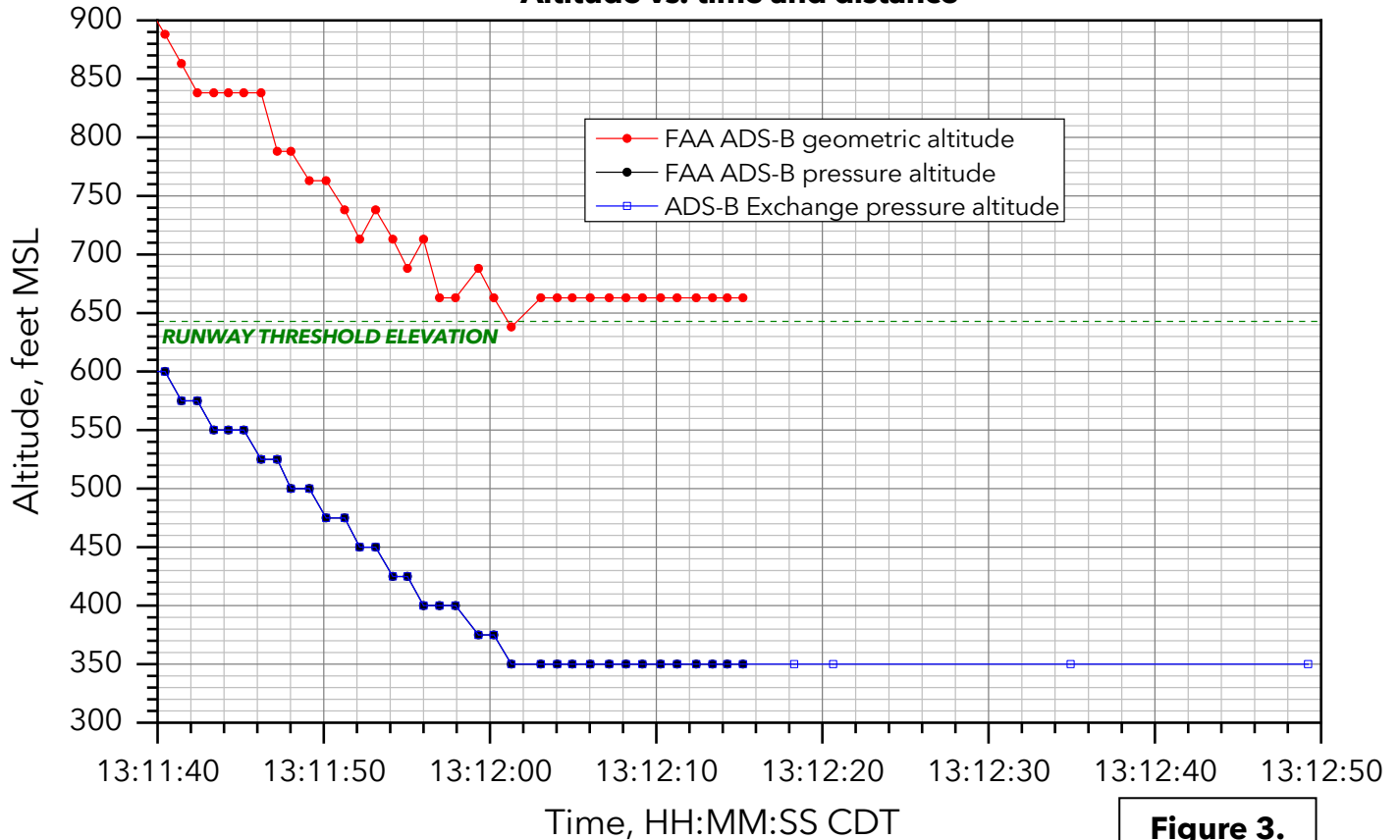


Figure 3.

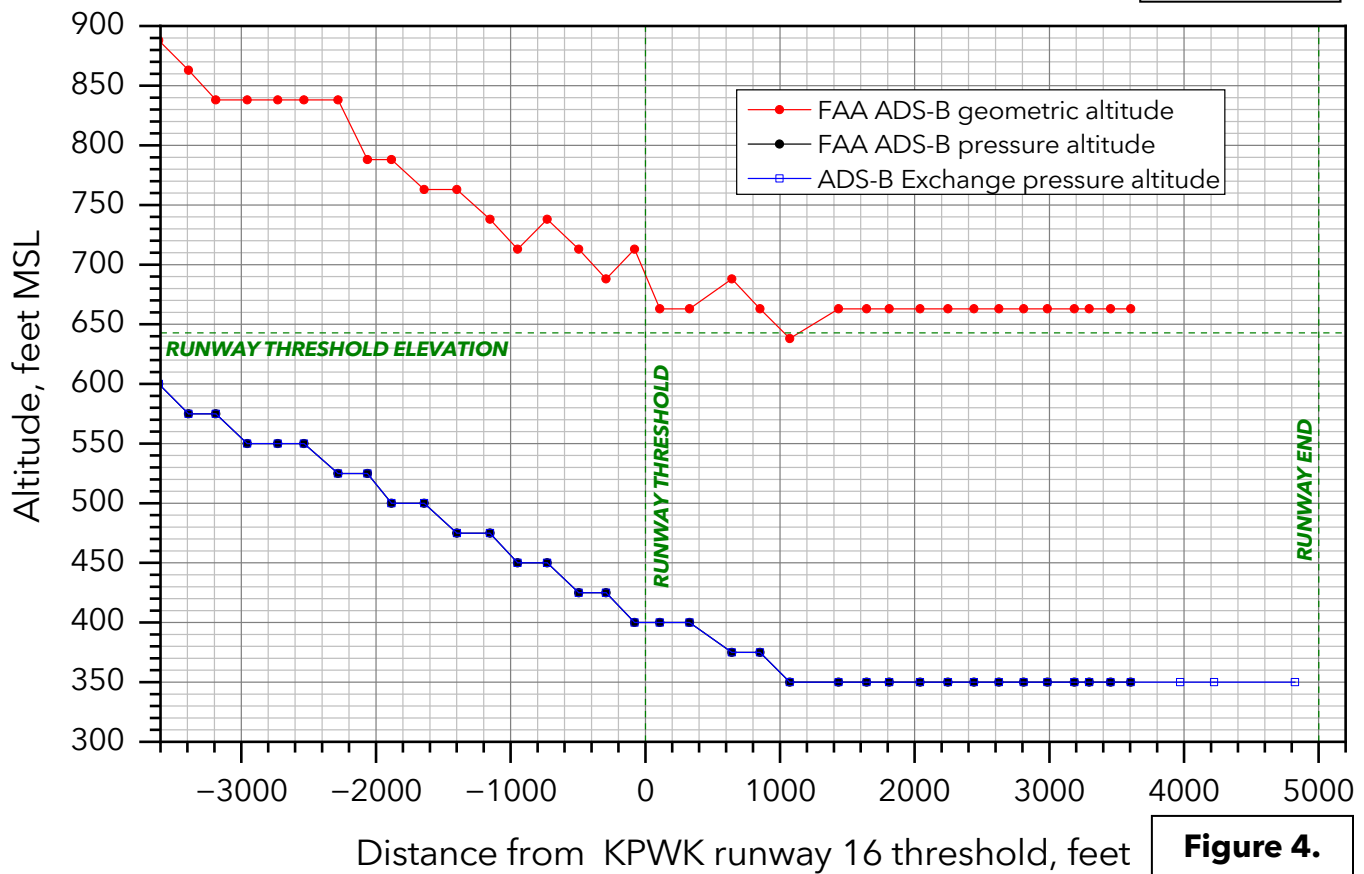


Figure 4.

CEN23LA403: IAI Astra, N39TT, Wheeling, IL 08/21/2023 **Simulated landing ground roll distances compared with ADS-B data**

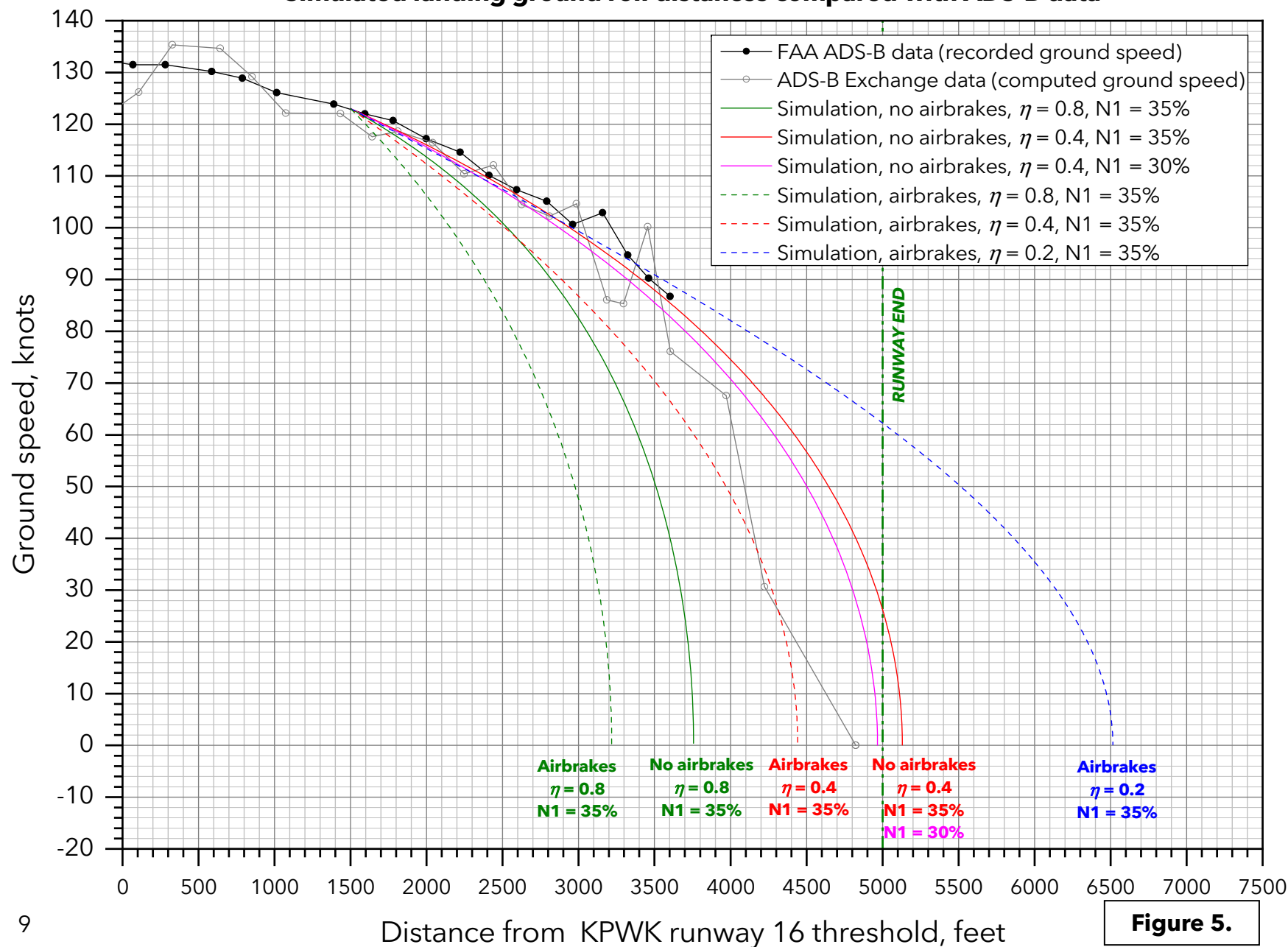


Figure 5.

CEN23LA403: IAI Astra, N39TT, Wheeling, IL 08/21/2023
Comparison of wheel braking friction coefficient models

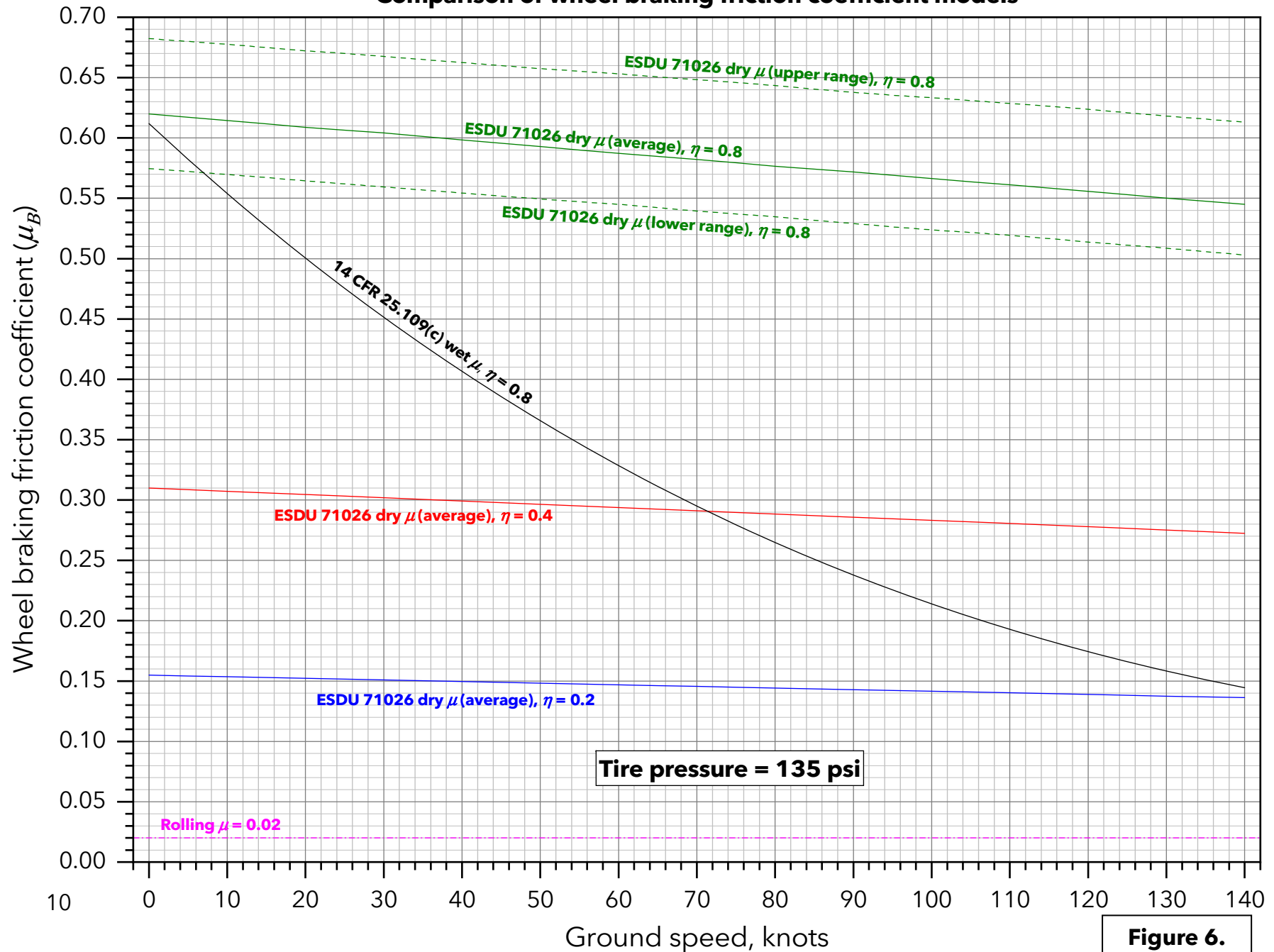


Figure 6.