Estimating the distance from the track at which maglev trains may generate a nuisance level of noise or vibration

Owen Kelley (okelley@gmu.edu), Greenbelt, Maryland; updated: 13 December 2017

***Disclaimer*:** The information, calculations, and opinions in the present document are informed by material available online. The author is a private citizen interested in the impacts of a proposed rail project in Maryland. The numerical estimates herein are intended merely to encourage reflection. Before relying on these estimates, they should be verified by a professional in the relevant field. Feedback is welcome.

1. Introduction

In October 2017, the environmental impact study announced three alternatives for the track alignment of the proposed superconducting maglev rail line between Baltimore and Washington DC (http://www.bwmaglev.info/). It is difficult for the public and for elected officials to form opinions about the impacts of these routes to their community when the material distributed by the environmental impact study lacks even the most rudimentary estimate of how far from the track the maglev train would generate a noise nuisance or a ground-vibration nuisance.

Fortunately, the Federal Railroad Administration (FRA) has published methods for estimating noise and ground-vibration nuisance that a high-speed train would produce. These methods were published in 2012 and can be downloaded from https://www.fra.dot.gov/eLib/details/L04090. The intended audience of FRA (2012) is professionals who are performing environmental impact studies (page 1-1), but some of the methods described in FRA (2012) may be understood and applied by the layman.

The present document is intended to provide an introduction to FRA (2012) and specifically to FRA (2012)'s methods for estimating how far from a maglev track three kinds of nuisances may extend. These nuisances are the noise level (that can disrupt sleep and other activities), the ground vibration (that can rattle homes), and the rapid onset of the noise (that can annoy or startle).

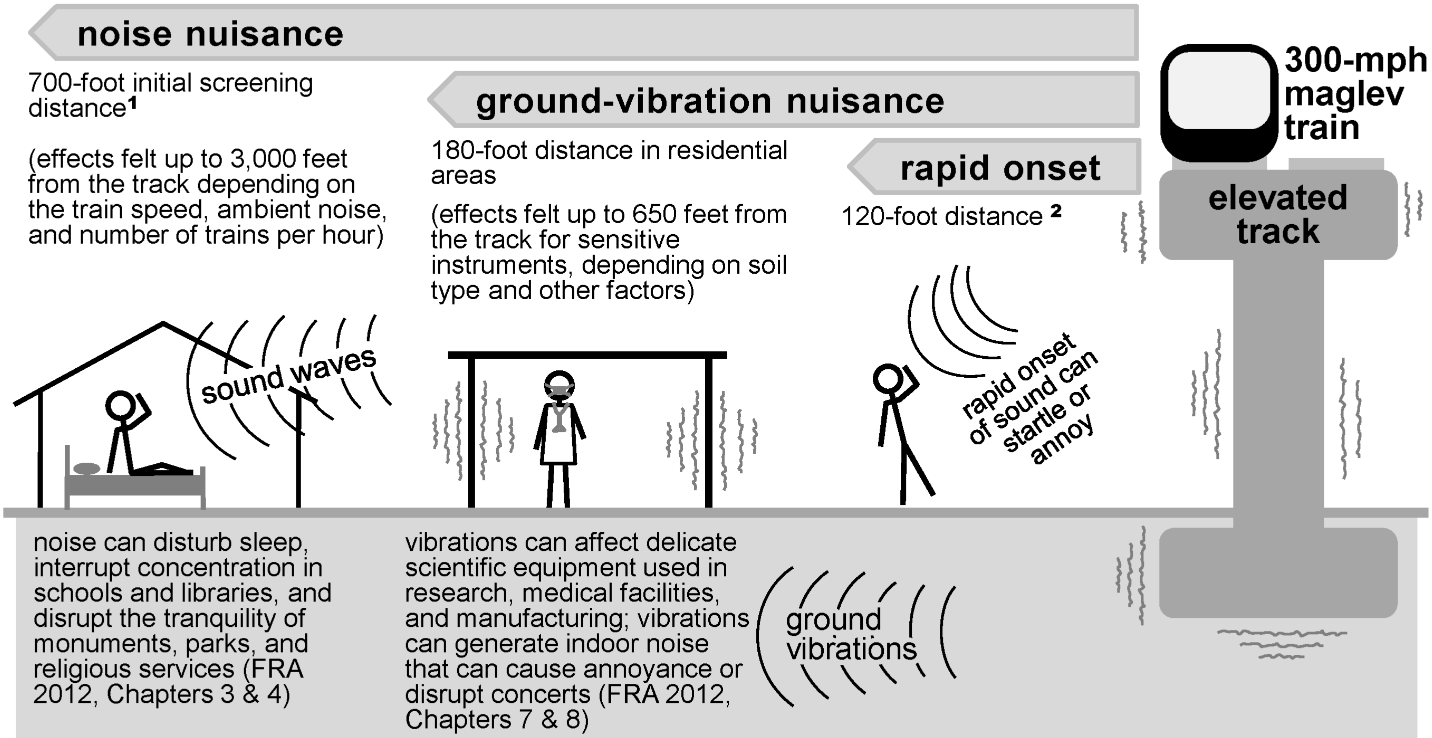
The research summarized in FRA (2012) shows that a maglev train travels fast enough to generate considerable noise and ground vibration despite the train's aerodynamic shape. During the day, the noise of a maglev train's passage may be particularly unwelcome in venues such as schools, day-care centers, hospitals, doctor and dentist offices, libraries, houses of worship, parks, monuments, or other places where a peaceful atmosphere is expected or concentration is required. During the night, the noise of a maglev train's passage may disrupt sleep. Some studies suggest that senior citizens may be particular susceptible to this effect whether sleeping in a private resident or a senior-care facility. The ground vibration from a maglev train creates a kind of "economic dead zone" near its track where certain kinds of research, manufacturing, and medical activities are prohibited.

For the public and elected officials to be able to comment meaningfully about the impacts of a proposed maglev rail line, it would be useful if maps were generated that display the areas that are close enough to the proposed track that they might suffer from noise or ground-vibration impact. Creating such a map is beyond the scope of the present document, but the present document does provide distances that could be used to create such maps. The nuisance distances provided in the present document go from track to observer, so the total width of the nuisance zone would be twice as great as the nuisance distance cited here. The noise and rapid-onset nuisances are associated only with the aboveground portion of the track. In contrast, the ground-vibration nuisance extends an equal horizontal distance on either side of the track regardless of whether the track is aboveground or underground according to FRA (2012).

Throughout the present document, 300 mph is used as the top speed of the maglev train even though a slightly higher speed is stated by the environmental impact study (311 mph). Using a round number for the train speed (i.e., 300 mph instead of 311 mph) in the present document avoids giving a false impression that these rough estimates are more accurate than they are. Another reason to use 300 instead of 311 mph as the top speed in the calculations of the present document is that it reduces the chance of overestimating the nuisance distances. At speeds around 300 mph, the distance that a nuisance extends from the track increases rapidly with train speed.

Although the present document does not explore this idea, one could speculate that the FRA (2012) methodology might underestimate the nuisance posed by the proposed Baltimore-Washington superconducting maglev rail line. One reason that this possibility cannot be ruled out is that, according to Wikipedia, no 300-mph superconducting maglev rail line has ever been built between two U.S. cities. In fact, the only segment of superconducting maglev line that has been constructed, anywhere in the world, is an 11-mile-long test segment of track that was built in Japan starting in 1997. This track underwent testing until 2011 (https://en.wikipedia.org/wiki/SCMaglev). In 2011, the Japanese government authorized the Central Japan Railroad Company to begin constructing the first commercially operational superconducting maglev line. This line is expected to become operational 16 years later (in 2027), connecting Tokyo and Nagoya. One might also question of whether there will be engineering obstacles, cost overruns, or quality-of-life issues that become apparent only after the world's first superconducting maglev line begins routine operation in Japan, assuming that it ever does.

Because the U.S. public has no experience with the noise and vibration nuisance that would be generated by a 300-mph train, there is considerable uncertainty about how strong would be the response of those subjected to the associated noise and vibration in their homes and in the parks, libraries, schools, places of worship, concert halls, theaters, monuments, hotels, and businesses that they frequent. Figure 1 is a schematic depiction of the three kinds of maglev nuisances that are described in FRA (2012) and subsequently in the present document.



[1] The initial screening distance is used to identify potentially impacted facilities before a general assessment is performed.
[2] FRA (2012, Figs. 2-5, 4-2). **Reference**: Federal Railroad Administration, 2012: *High-speed Ground Transportation Noise and Vibration Impact Assessment*, Final Report, September 2012. U.S. Dept. of Transportation, DOT / FRA / ORD - 12/15, 248 pp. Available online at https://www.fra.dot.gov/eLib/details/L04090.

Figure 1. A schematic representation of three nuisances associated with a maglev train: noise nuisance, ground-vibration nuisance, and rapid-onset nuisance.

2. Noise nuisance

2a. Initial screening for noise nuisance

According to FRA (2012, pg. 4-2), initial screening is a useful technique because it can be applied when only a few parameters are known about the proposed rail project and the impacted communities. The purpose of initial screening is to generate a list of properties that are near enough to a proposed track alignment that these properties should be examined more carefully by a subsequent "detailed analysis" (FRA 2012, pg. 5-1). A list of the kinds of noise-sensitive features that one should look for during the initial screening is found in FRA (2012, pg.

3-7). There is also a third method, whose complexity and accuracy lies somewhere between initial screening and detailed analysis. This middle method is called a "general assessment" (FRA 2012, pg. 4-4).

For a noise nuisance, one can read an initial-screening distance from FRA (2012) Table 4-1. To choose a value from this table, one needs an estimate of the pre-existing noise conditions and the speed of the train. The quieter the pre-existing conditions, the further from the tracks that the new maglev noise will be experienced as a nuisance. Aerodynamic noise dramatically increases with train speed, so the noise of the maglev train's passage is a nuisance further from the track when the train is traveling faster.

For the purpose of determining a noise-nuisance initial-screening distance, many residential areas, parks, forests, and farmland might reasonably be treated as "quiet suburban." Table 4-6 and page 4-12 of FRA (2012) suggest that "loud suburban" conditions are likely to occur within 400 feet of a superhighway, within 200 feet of a major road with at least 300 trucks passing per hour, or where the population density is high (≥10,000 persons per square mile).

Table 4-1 provides three variations on both quiet and loud suburban conditions. From noisiest to most quiet, these three variants are that the new maglev track is being built next to an existing highway, next to an existing train track, or in a location with no such transportation infrastructure. Table 1 (below) of the present document was created by extracting values from FRA (2012) Table 4-1 that correspond to the middle of these three variants (i.e., existing rail corridor). The distances quoted in Table 1 of the present document would vary by no more than ±100 feet if one of the other variants were chosen from FRA (2012) Table 4-1.

To use Table 1 of the present document, one needs an estimate of where along the proposed aboveground track alignments the maglev train will be traveling at least 200 mph. Section 5d of the present document provides such an estimate under the route alignments proposed in October 2017 for the Baltimore-Washington superconducting maglev rail project. In brief, section 5d estimates that the maglev train would likely be traveling ≥200 mph at least from Bladensburg to Fort Meade. The ≥200 mph portion of the track would include all of the aboveground track of the October 2017 proposed routes. The aboveground portion of the track goes from Greenbelt to Fort Meade under alternatives J and J1 and from Glen Dale to Bowie and Fort Meade under alternative E.

Table 1. Initial-screening distance for noise nuisance for an aboveground maglev track, based on FRA (2012) Table 4-1.[a]

	Maglev train speed	
	<200 mph	≥200 mph [b]
Noisy suburban	50 feet	400 feet
Quiet suburban	50 feet	700 feet

[a] The initial-screening distance would vary from the values stated here by no more than ±100 feet if different variants of noisy and quiet suburban environments were selected from FRA (2012) Table 4-1.

[b] Under all route alignments proposed in October 2017 for the Baltimore-Washington superconducting maglev rail project, the maglev would likely be traveling at least 200 mph along all of the aboveground portions of the track between Bladensburg and Fort Meade.

2b. General assessment of noise nuisance

The FRA (2012) general-assessment method for noise nuisance involves more steps than the just-described initial-screening technique for noise nuisance. Table 2 of the present document was calculated using a simplified form of the FRA (2012) general-assessment method, as described in detail in section 5a of the present document.

Comparing the initial screening (Table 1, above) with the general assessment (Table 2, below), one sees that the general-assessment distance for 200 mph trains is generally consistent with the initial-screening distance. For example, for quiet pre-existing conditions, the initial-screening distance is 50 or 700 feet for trains traveling under or over 200 mph, while the general-assessment distance is 366–498 feet for trains traveling at 200 mph depending on whether the track is elevated or at ground level.

In contrast, the general-assessment distance for a maglev train traveling specifically at 300 mph is considerably greater than the initial-screening distance for the broad category of all trains traveling at least 200 mph. For example, under quiet pre-existing conditions and for 4 trains per hour that travel 300 mph along an elevated track, the general-assessment noise nuisance would extend 1,933 feet from the track. In comparison, the closest category in the initial screening would be the noise nuisance extending 700 feet from the track if the trains were traveling at ≥200 mph in quiet pre-existing conditions. A plausible explanation for the difference between general assessment and initial screening for a 300-mph train is that FRA (2012) may have optimized its initial-screening "≥200-mph category" for trains that are traveling merely 200–250 mph, not 300 mph.

Table 2. The distance from the track that the noise nuisance extends when the track is aboveground, based on FRA (2012, Chapter 4).

Background sound level	Quite, suburban (50 dBA)		Loud, suburban (60 dBA)	
Train speed [a]	300 mph	200 mph	300 mph	200 mph
4 trains per hour				
Elevated track	1,933 ft	498 ft	895 ft	231 ft
Track at ground level	1,421 ft	366 ft	658 ft	169 ft
8 trains per hour				
Elevated track	3,074 ft	792 ft	1,423 ft	366 ft
Track at ground level	2,259 ft	582 ft	1,046 ft	269 ft

[a] As described in section 5d of the present document, a reasonable assumption of 0.05*g* acceleration results in the proposed Baltimore-Washington maglev train traveling ≥200 mph from Bladensburg to Fort Meade. Under the same assumption, the train would be traveling at 300 mph between Greenbelt and the Patuxent Wildlife Research Refuge on alternative routes J and J1 and also at 300 mph between Bowie and the Patuxent Wildlife Research Refuge on alternative route E.

3. Ground-vibration nuisance

To estimate the distance from a maglev train at which a ground-vibration nuisance exists, one must use the FRA (2012) general-assessment method rather than an initial screening. This is necessary because FRA (2012, Table 8-1) only provides an initial-screening distance for the ground-vibration nuisance of steel-wheeled trains, not maglev trains.

In Chapters 7 and 8, FRA (2012)'s general-assessment method provides a ground-vibration nuisance distance that depends on three factors. One factor is the speed of the train, such as 200 mph or 300 mph. As described in section 5d of the present document, the alternative routes proposed in October 2017 for the Baltimore-Washington superconductive maglev train would likely have the train traveling ≥200 mph at least from Bladensburg to Fort Meade. The train is likely to travel at 300 mph from Greenbelt to the Patuxent Wildlife Research Refuge under alternative routes J and J1. The train is also likely to travel at 300 mph from Bowie State University to the Patuxent Wildlife Research Refuge under alternative route E.

A second factor is that the ground-vibration nuisance extends a different distance from the track depending on the use of the building. Given at least 70 train passbys per day, FRA (2012) deems that a train-induced vibrational level of 65 VdB is acceptable for concert halls, recording studios, and most buildings that contain moderately-sensitive laboratory or manufacturing equipment. FRA (2012) deems that a higher vibrational level of 72 VdB is acceptable for residences, operating rooms, auditoriums, and theaters (pg. 7-3 and Table 7-2). These vibrational levels can occur at the distances from the track that are specified in Table 3 of the present document. Section 5b of the present document shows how the values in Table 3 can be traced to the guidelines in FRA (2012).

Table 3. Distance that the ground-vibration nuisance would extend from either an aboveground or belowground maglev track, based on FRA (2012) Tables 7-1, 7-2, and 8-2 and Figure 8-1.

	Maglev train speed	
Building type (acceptable vibration threshold)	200 mph	300 mph
Normal soil propagation (the default assumption)		
Residential area, operating room (72 VdB)	60 feet	180 feet
Research, manufacturing, or medical facilities with vibration-sensitive equipment; concert halls (65 VdB)	130 feet	300 feet
Efficient soil propagation (only where indicated by seismic tests)		
Residential area, operating room (72 VdB)	180 feet	400 feet
Research, manufacturing, or medical facility with vibration-sensitive equipment; concert halls (65 VdB)	300 feet	650 feet

4. Rapid-onset nuisance

When a high-speed train approaches, the rapid crescendo of noise can be an annoyance independent of the loudness of the noise itself. Near to the track, the sound's rapid onset is able to surprise and startle, not merely annoy. The sound of a high-speed train's passage is mostly confined to a period of about 5 to 10 seconds (depending on how fast the train is moving), which includes about two seconds of rapid increase in the sound level followed by several seconds of decreasing volume (FRA 2012, Fig. 2-3). The faster the train, the more extreme the crescendo.

For various train speeds, FRA (2012, Fig. 2-5) can be used to estimate the distance at which rapid onset is an annoyance. Interpolating or extrapolating along the straight line shown in FRA (2012, Fig. 4-2), one can estimate the distance at which rapid onset can surprise or startle. Table 4 below summarizes these values. Section 5c of the present document provides details of how Table 4 below is consistent with FRA (2012).

Table 4. Distance from the track that a nuisance may extend due to the rapid onset of the noise of the maglev train's passage, based on FRA (2012) Figures 2-5 and 4-2.

	Maglev train speed	
Impact (sound-onset rate)	200 mph	300 mph
Annoyance (15 dBA s^{-1})	80 feet	120 feet
Surprise or startle (30 dBA s^{-1})	42 feet	63 feet

5. Mathematical details

5a. Mathematical details of noise nuisance

The FRA (2012) general-assessment method for noise nuisance allows one to calculate the distance from the track at which a noise nuisance may be experienced. The input variables include the speed v (mph) of the train at the time it passes the observer, the number n_{train} of trains per hour that pass the observer, the background sound level at the observer's location in the absence of the maglev train, and whether or not the train track is elevated or at ground level.

A Microsoft Excel spreadsheet is available on the Federal Railroad Administration website that performs these calculations, except for factoring in the effect of an elevated track. Using this spreadsheet, one can verify the present document's implementation of the general-assessment noise-nuisance equations from FRA (2012). The only missing parameter in the Federal Railroad Administration's spreadsheet is the +2 dBA adjustment for an elevated track.

Step #1: Identify the fixed parameters that FRA (2012) provides for a maglev train traveling at a speed of 200 mph or faster. These three fixed parameters are the reference value for the equivalent sound level SEL_{ref} (78 dBA) of the passage of one maglev train, the distance from the tracks at which the reference sound level would be observed d_{ref} (50 feet), and the reference train speed v_{ref} (120 mph). These three fixed parameters are given in Table 4-3 of FRA (2012).

Step #2: Choose the values for the input variables. For example, one chooses the number of trains per hour (n_{train}). In the examples worked in the present document, n_{train} is taken to be 4 or 8 trains per hour. These values correspond to one northbound or southbound train passing by every 15 minutes when n_{train}=4 or every 7.5 minutes when n_{train}=8. The ongoing Baltimore-Washington maglev environmental impact study appears not to have provided an estimated range for the number of trains per hour on their website or on the poster boards that they displayed at the public meetings that they hosted in the fall of 2017. For this reason, the present document takes, as a starting point, the number of trains per hour that was published in the 2003 draft environmental impact study for a maglev line between Baltimore and Washington, a maglev line that was never built. Specifically, the 2003 study expected 2-5 trains per hour initially, increasing to 8 trains per hour during peak hours "as ridership develops" (MDOT 2003, pg. ES-13).

Also, one chooses from a table in FRA (2012) the correction factor C (dBA) that corresponds to the track's relationship to ground level and any applicable sound shielding. For the examples worked in the present document, it is assumed that the train track is either elevated (C = +2dBA) or the track is at ground level (C = 0). One chooses the speed v (mph) of the train at the time it passes the observer. For the examples worked in the present document, speed is taken to be 200 or 300 mph.

Step #3: Determine the pre-existing background noise level without any maglev trains. In a quiet pre-existing environment, a quieter maglev sound would be sufficient to create a nuisance (FRA 2012, Tables 3-4, 4-1, 4-2). In a louder pre-existing environment, a louder maglev sound would be required to create a nuisance. FRA (2012) describes a quiet, suburban environment as having a day-night sound level (L_{dn}) of 50 dBA, equivalent to that location having a constant noise level of 50 dBA measured by a sound meter. Obviously, most environments have fluctuating sound levels throughout the day, so to have a 50 dBA value for L_{dn}, the instantaneous sound level would have to be somewhat lower than 50 dBA most of the time, punctuated by periods when it exceeds 50 dBA. FRA (2012) describes a loud, suburban environment as having a 60 dBA value for L_{nd}. As a point of reference, the U.S. Department of Housing and Urban Development has determined that an ambient sound level of L_{dn} ≥65 dBA is inappropriate in residential areas (FRA 2012, Appendix A, pg. A-13).

Step #4: Based on the pre-existing noise level, identify the cutoff for the amount of maglev-generated noise that would constitute a nuisance. FRA (2012, Table 3-4) states the minimum level ($L_{dn,cutoff}$) of maglev-generated noise that would constitute a nuisance. In a quiet, suburban environment (50 dBA background), a maglev-generated sound level that increases the total sound level by 5 dBA is sufficient to create a nuisance (i.e., $L_{dn,cutoff}$= 53 dBA). In a loud suburban environment (60 dBA background), a maglev-generated sound level that increases the total sound level by 2 dBA is sufficient to create a nuisance (i.e., $L_{dn,cutoff}$ = 58 dBA).

Step #5: Calculate the equivalent sound level SEL (dBA) generated by a single passage of the train at the reference distance and the train's actual speed v (mph). The SEL is the sound level during one second that would contain the same amount of sound energy as the actual 5–10 second sound of the passage of the train.

$$SEL = SEL_{ref} + 50\ log_{10}\left(v/v_{ref}\right) \qquad \textit{Eq. 1}$$

Pausing the derivation for a moment, one can use Equation 1 to get a sense of how loud an individual passby of the maglev train could be. Substituting a 300-mph speed into Equation 1 results in an equivalent sound level of 97.9 dBA = 78 + 50 $\log_{10}$(300 mph / 120 mph) at a 50-foot distance from the track. The example in Figure 2-3 of FRA (2012) suggests that the maglev's maximum sound level at a 50-foot distance from the track would be a few dB less (i.e., ~95 dBA) than the SEL at the same 50-foot distance. To mention two of the comparisons that are made on page 2-3 of FRA (2012), a ~95 dBA maximum sound level 50 feet from the maglev track would make the maglev twice as loud as a jackhammer 50 feet away and similar in loudness to a power tool (e.g., an electric drill or circular saw) held at arm's length.

Equation 2 calculates the hourly equivalent sound energy, $L_{eq}[h]$ in dBA, for all train events during the busiest hour of the day at the reference distance, d_{ref} (feet). As a simplifying assumption, the following calculations assume an equal number of trains each hour of the day. Equation 2's last term is -35.6 dB, which is equivalent to dividing by 3600 in linear units (n.b., 3600 seconds = 1 hour) because SEL is a per-second quantity and $L_{eq}[h]$ is a per-hour quantity. Values for C and n_{train} can be found above in step #2.

$$x = L_{eq}[h] = SEL + 10\ log_{10}(n_{train}) + C - 35.6 \qquad \textit{Eq. 2}$$

Equation 3 calculates the day-night sound level, $L_{dn,ref}$ also in dBA, at the reference distance.

$$L_{dn,ref} = 10\ log_{10}\left(\ 15\ \cdot\ 10^{x/10} + 9\ \cdot\ 10^{(x+10)/10}\right) - 13.8 \qquad \textit{Eq. 3}$$

Consistent with FRA (2012), Equation 3 assumes 15 hours of daytime, 9 hours of nighttime, and a 10 dBA "penalty" for noise during nighttime. Incidentally, the subtraction of 13.8 dBA in Equation 3 is equivalent to dividing the linear total for all hours of the day by 24 hours to produce a daily-average value. Equations 1 to 3 of the present document can be found in Table 4-5 of FRA (2012).

Step #6: Estimate the distance at which the sound-level at 50 feet drops to the cutoff sound level that still produces a nuisance. FRA (2012, pg. 4-9) states that the day-night sound level falls off according to Equation 4:

$$L_{dn} = L_{dn,ref} - 15\ log_{10}\left(d/d_{ref}\right) \qquad \textit{Eq. 4}$$

Equation 4 is equivalent to saying that the day-night sound level drops off by 4.5 dB for each doubling of the distance beyond the reference distance d_{ref}. This fact can be shown by evaluating the rightmost term of Equation 4 for a distance twice as great as the reference distance, i.e., 15 $\log_{10}$ ($2d_{ref}$ / d_{ref}) = 15 $\log_{10} 2 \approx 4.5$ dB. Based on this fact, a formula for the distance $d_{nuisance}$ (feet) at which the day-night sound level drops to the minimum nuisance level $L_{dn,cutoff}$ (dBA) would be the following:

$$d_{nuisance} = d_{ref}\ \cdot\ 2^{\left(\ L_{dn,ref}\ -\ L_{dn,cutoff}\ \right)\ /\ 4.5dB} \qquad \textit{Eq. 5}$$

The distances stated in Table 1 of the present document are calculated from Equation 5.

5b. Mathematical details of ground-vibration nuisance

A reference curve is used to obtain the distance from the track that a ground-vibration nuisance exists at various train speeds. Specifically, one uses the 150-mph maglev reference curve that is shown in Figure 8-1 of FRA (2012) and the adjustment factors that are provided in Table 8-2 of FRA (2012). Figure 2 below applies these adjustment factors to the reference curve for several cases: a maglev train traveling 200 mph or 300 mph over ground that has normal or efficient propagation. The distance of interest can be identified as the intersection of the adjusted curve with the horizontal line that represents the 72 VdB or 65 VdB nuisance threshold for residential or high-sensitivity locations, respectively.

Consistent with FRA (2012), Figure 2 of the present document adjusts the reference curve by +4 dB for 200 mph trains and +14 dB for 300-mph trains. In addition, a +10 dB adjustment should be applied if a geological site investigation determines that the soil at a particular location is an efficient propagator of vibration. In the future, a general assessment of ground-vibration nuisance may determine that other adjustment factors are relevant. For example, a +2 dB adjustment should be applied if it were decided that the maglev would ride on a hybrid steel and concrete track, as opposed to the concrete-only track assumed in the present document. A +6 dB adjustment should be applied in the calculation of vibration impact to any building that is found to have a high level of resonance in its floors, walls, or ceilings.

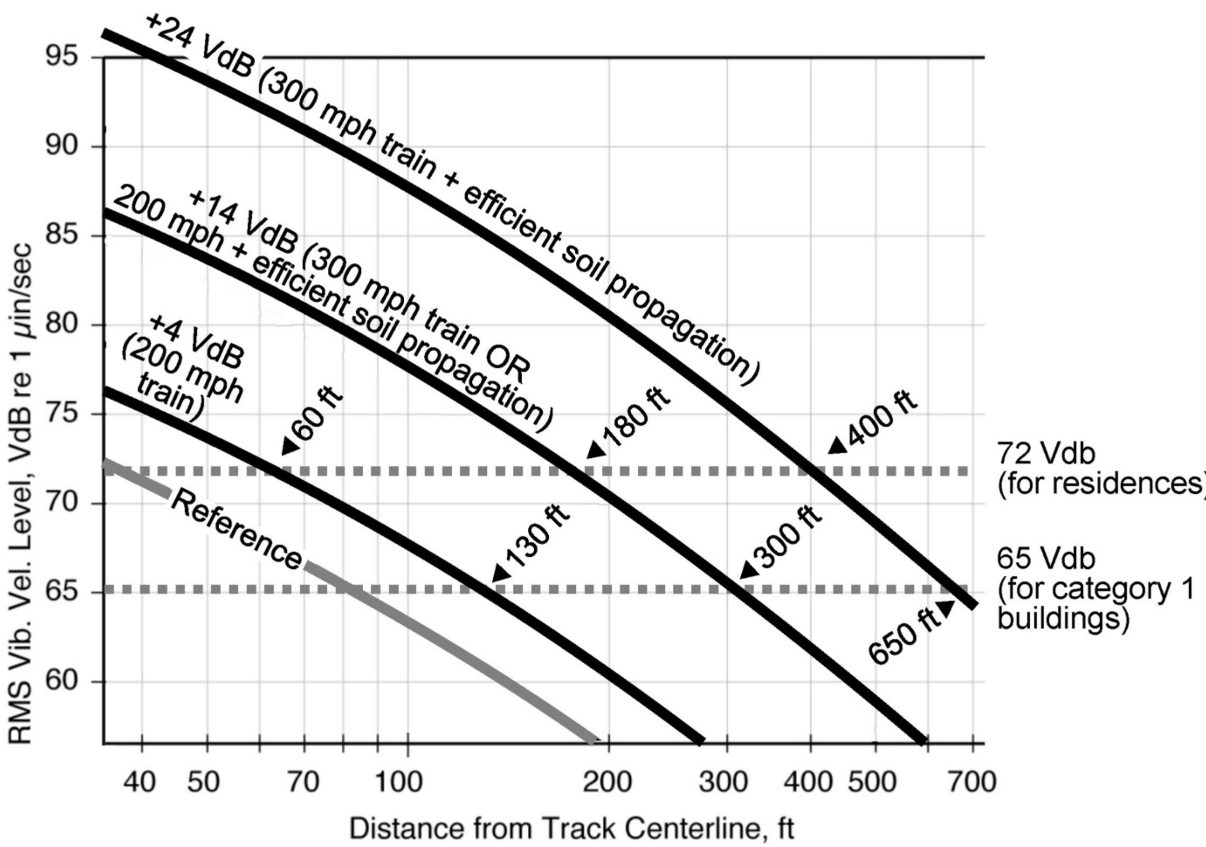


Figure 2. Ground-vibration nuisance distance based on Figure 8-1 of FRA (2012) and adjustment factors stated in Table 8-2 of FRA (2012).

5c. Mathematical details of rapid-onset nuisance

Research has found that the rapid crescendo of an approaching maglev train can be annoying or startling to human subjects. FRA (2012) treats "rapid onset" as a separate nuisance factor from the actual volume of the sound of a maglev train's passage.

Using the ratio shown in FRA (2012, Fig. 2-5), one can estimate the maximum distance from the track at which rapid onset is an annoyance. Specifically, annoyance occurs when the onset rate is at least 15 dBA per second, which occurs when the ratio between speed (mph) and distance (feet) is 2.5. For a maglev train traveling at 200 or 300 mph, this ratio of 2.5 works out to an 80 or 120 foot distance from the track, respectively.

Figure 4-2 of FRA (2012) shows the distance from the track at which rapid onset can surprise and startle. The startle effect occurs when the onset rate is at least 30 dBA per second, which occurs up to 42 feet from the track at 200 mph. Extrapolating the straight line shown in Figure 4-2 of FRA (2012) from 250 to 300 mph, one estimates that, at 300 mph, the startle distance would be 63 feet.

5d. Variation in maglev speed as a function of distance from the nearest station

The following schematic diagram depicts one possibility for the train-speed variation along the two main track alignments proposed in October 2017 for the Baltimore-Washington superconducting maglev project. This section explains why this speed-distance profile is a reasonable guess, although it may be may an underestimate. This speed-distance profile assumes a 300-mph top speed and an acceleration of 0.05*g*, i.e., a horizontal speed increase of 5% of the acceleration due to gravity (9.8 m s^{-1}).

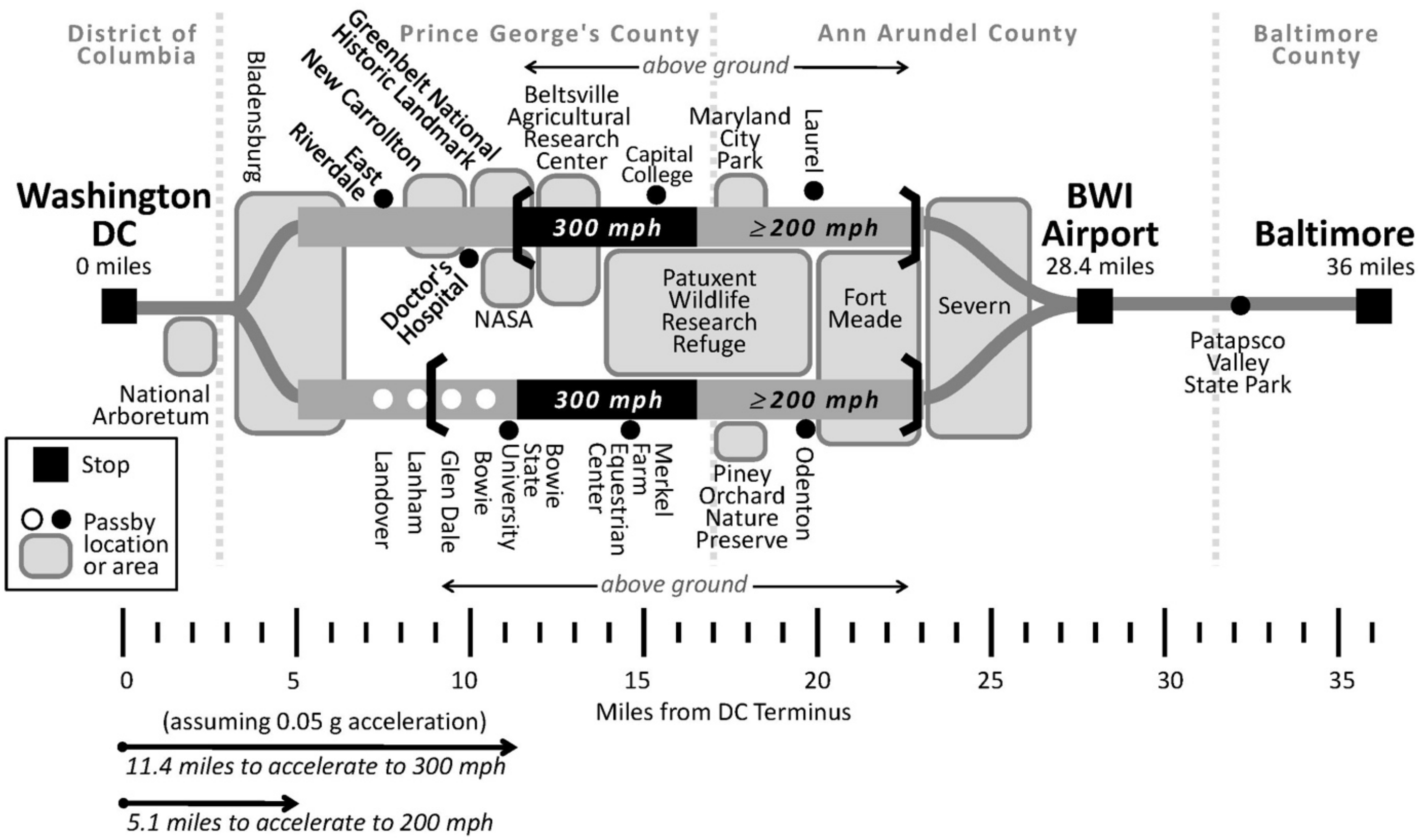


Figure 3. Schematic diagram of one possible speed-distance relationship for the October 2017 proposed routes for the Baltimore-Washington superconducting maglev rail line. This speed-distance profile assumes a constant 0.05*g* acceleration up to an assumed maximum speed of 300 mph.

If one assumes an 0.05*g* acceleration rate, then the BWI airport station would be too close to the Baltimore station for the train to reach 200 mph in between these two stations. Assuming an 0.05*g* acceleration, it is only in the longer stretch of track between Washington and BWI that the maglev can reach a 300-mph speed. For this reason, it appears unlikely that the maglev project would add a stop in Prince George's County (such as in New Carrollton). A superconductive maglev train that made four stops (Washington, PG County, BWI airport, and Baltimore) would not be able to reach 300 mph anywhere between Baltimore and Washington.

To estimate the speed of a maglev train along a proposed track route, one may assume, as a first approximation, a constant acceleration leaving a station until the train reaches its maximum speed, followed by period of constant speed, followed by a period of constant deceleration as the train approaches a stop at the next station. The assumption of a constant 0.05*g* acceleration and deceleration is likely to be fairly accurate because it enables one to reproduce fairly closely the speed profile published in the 2003 draft environmental impact statement for a previously proposed (and never built) maglev rail line between Baltimore and Washington (MDOT 2003, pg. ES-14). Specifically, MDOT issued in 2003 a draft impact statement for a maglev train based on German technology to operate between Baltimore and Washington with the same three stops as the currently-proposed superconducting maglev rail line that is based on Japanese technology.

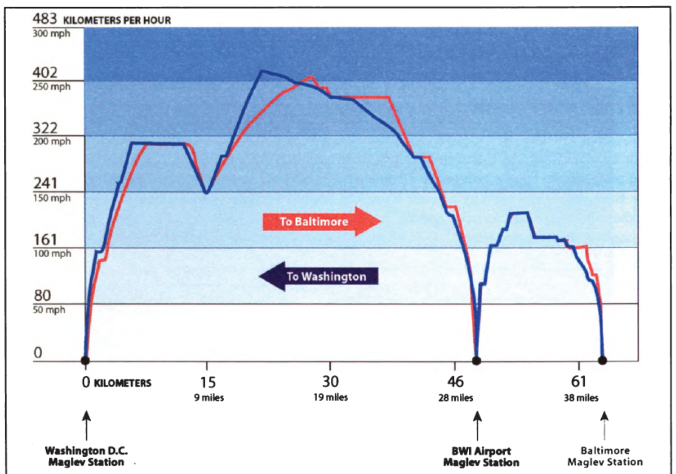


FIGURE ES.8
MAGLEV SPEED PROFILE (JUNE 2003)

2003 draft envir impact statement DC-Balto Maglev, pg 42 of 770 from pdf downloaded from http://books.google.com

Figure 4. The speed profile published in the 2003 draft environmental impact statement for a maglev rail line between Baltimore and Washington, a rail line that was never built.

Accelerating at 0.05*g*, a 200-mph speed is achieved approximately 5.1 miles from a station and a 300-mph speed is achieved approximately 11.4 km from a station. It is possible that the 2017 proposed superconducting maglev (with a 300-mph top speed) will accelerate more quickly than the 2003 proposed maglev (with a top speed of 250 mph). As a rule of thumb, 0.10*g* is the upper limit for train acceleration that permits passengers to walk comfortably through the cabin (Morris 2004). At 0.10*g*, a train would reach 200 mph approximately 2.5 miles from the station and 300 mph approximately 5 miles from the station.

Using the 0.05*g* acceleration/deceleration rate, the following calculation determines distance from the station at which a 200 or 300 mph train speed is reached. In these equations, the target train speed v_{final} is 200 mph or 300 mph. The assumed acceleration rate a is 3,946 miles per hour^2, where $a = 0.05g = 0.05\ (9.8\ \text{m s}^{-2})(3600\ \text{s h}^{-1})^2\ (3.28\ \text{feet meter}^{-1})\ (1\ \text{mile} / 5{,}280\ \text{feet})$. From these values, one calculates the time t that it takes the train to reach 200 or 300 mph using the equation $t = v / a$. The resulting time is 0.0507 and 0.0760 hours. Then, using time and final speed, one calculates distance d (miles) from the station using equation $d = (v_{final} / 2)\ t$. The resulting distance is 5.1 or 11.4 miles from the station to the point on the track where the train reaches 200 or 300 mph.

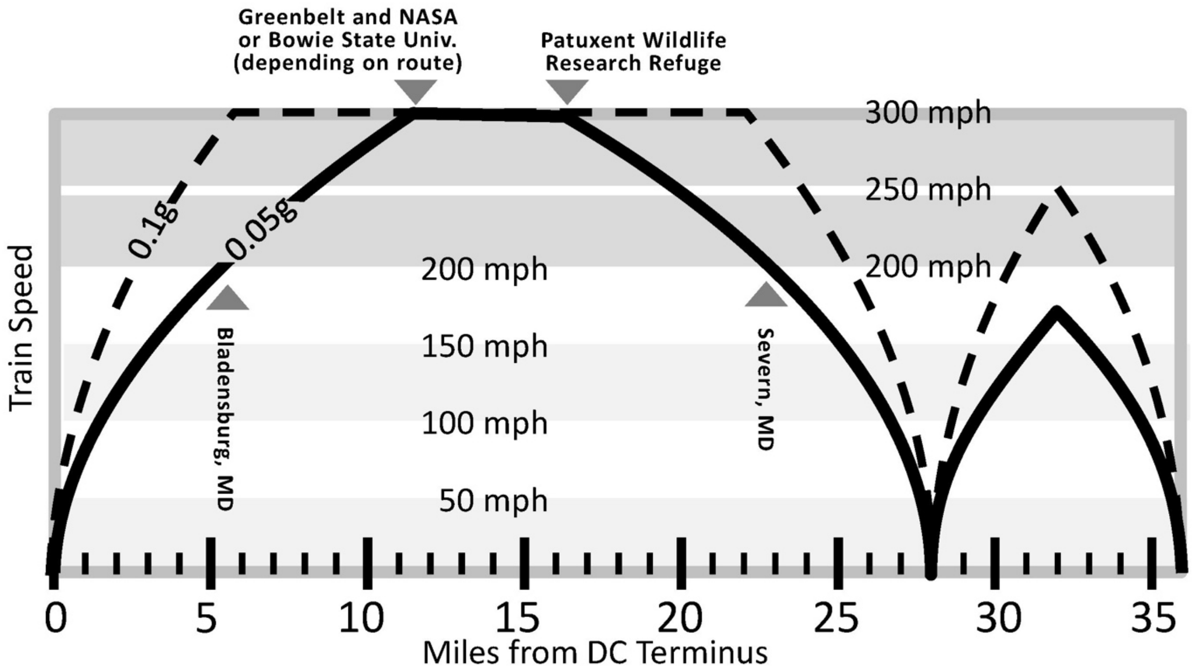


Figure 5. The speed profile between Washington and Baltimore for the proposed superconducting maglev train that would result from assuming an acceleration of 0.05*g* or 0.10*g* up to a 300-mph maximum speed.

6. Comparison with official estimates

It would be desirable to compare the geographic extent of noise and vibration nuisance stated in the present document with such estimates from other sources. For example, such estimates could include an official estimate from the federally-funded environmental impact study for the Baltimore-Washington superconducting maglev rail line or an engineering estimate from the company (Baltimore Washington Rapid Rail) that seeks to construct this maglev line. Ideally, these organizations would provide sufficient information that one could reproduce their estimates from the documentation that they provide. Such documentation might include the values of input parameters, equations, and data tables.

Unfortunately, it appears that neither the environment impact study nor the company that wishes to build the Baltimore-Washington maglev line chose to publish even a rough depiction of the geographic extent of the noise and vibration nuisance along the propose alignments prior to the public comment period in the fall of 2017. The online, interactive map (an online GIS) that the environmental impact study did make available at that time used merely a thin line to indicate the proposed location for the track (http://www.bwmaglev.info/). The amount of additional effort that the impact study would have had to expend to estimate the width of a noise or vibration nuisance polygon would have varied from trivial (reading a value from a table) to minimal (evaluating a few equations with a handheld calculator) based on the 2012 Federal Railroad Administration "initial screening" or "general assessment" guidelines, as earlier sections of the present document have described.

In 2017, poster boards describing the Baltimore-Washington maglev project were available on the environmental impact study's website (http://www.bwmaglev.info/), but they lack even a rough estimate of the geographic extent of the noise and vibration nuisance. This set of poster boards was also on display at public meetings hosted by the environmental impact study in the fall of 2017.

In addition, there were some poster boards that did contain information about noise and vibration that were displayed at the fall 2017 public meetings, but this second set of poster boards does not appear on the website of the maglev environmental impact study. After some research, this second set of poster boards was located among the "marketing material" on the website of the Northeast Maglev company (http://northeastmaglev.com; TNEM 2017).

These poster boards appear to constitute the most detailed, official account of the noise and vibration nuisance specific to the Baltimore-Washington maglev project that was available to the public in the fall of 2017. The two relevant poster boards also contain statements that seem unnecessarily imprecise, irrelevant, or misleading when compared to federal guidelines for estimating maglev noise and vibration nuisance. These two poster boards are shown below with commentary added by the present document in an italicized, colored font.

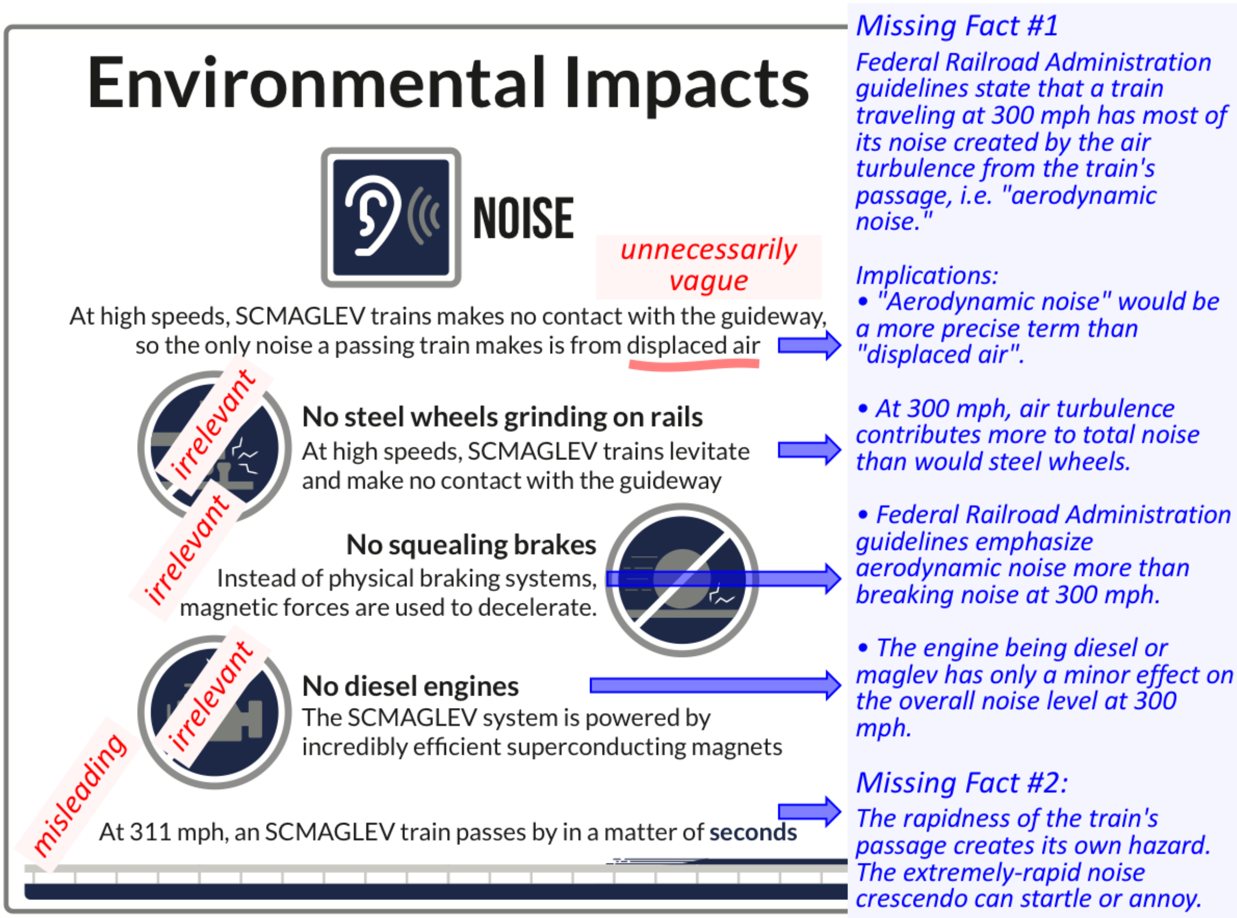


Figure 6. A poster board displayed at a public meeting hosted by the environmental impact study in the fall of 2017. This poster board describes, to a degree, the noise nuisance that would be generated by the passage of the proposed Baltimore-Washington superconducting maglev train (black text). The present document adds commentary in red and blue italicized text.

The poster board shown in Figure 6 lacks a quantitative estimate of the geographic extent of the maglev *noise* nuisance, and furthermore, it fails to mention relevant facts from FRA (2012). First, FRA (2012) states that most of the noise associated with a 300-mph train's passage is generated by air turbulence, i.e., aerodynamic noise. An important implication of this fact is that the type of engine (maglev or non-maglev) has little impact on the overall noise level of a train traveling at 300 mph. Second, FRA (2012) states that the rapidness of the passage of a 300-mph train actually introduces a new hazard that is not present for trains traveling at slower speeds. Specifically, the rapid passage of the train causes a rapid onset of noise, which can startle or annoy.

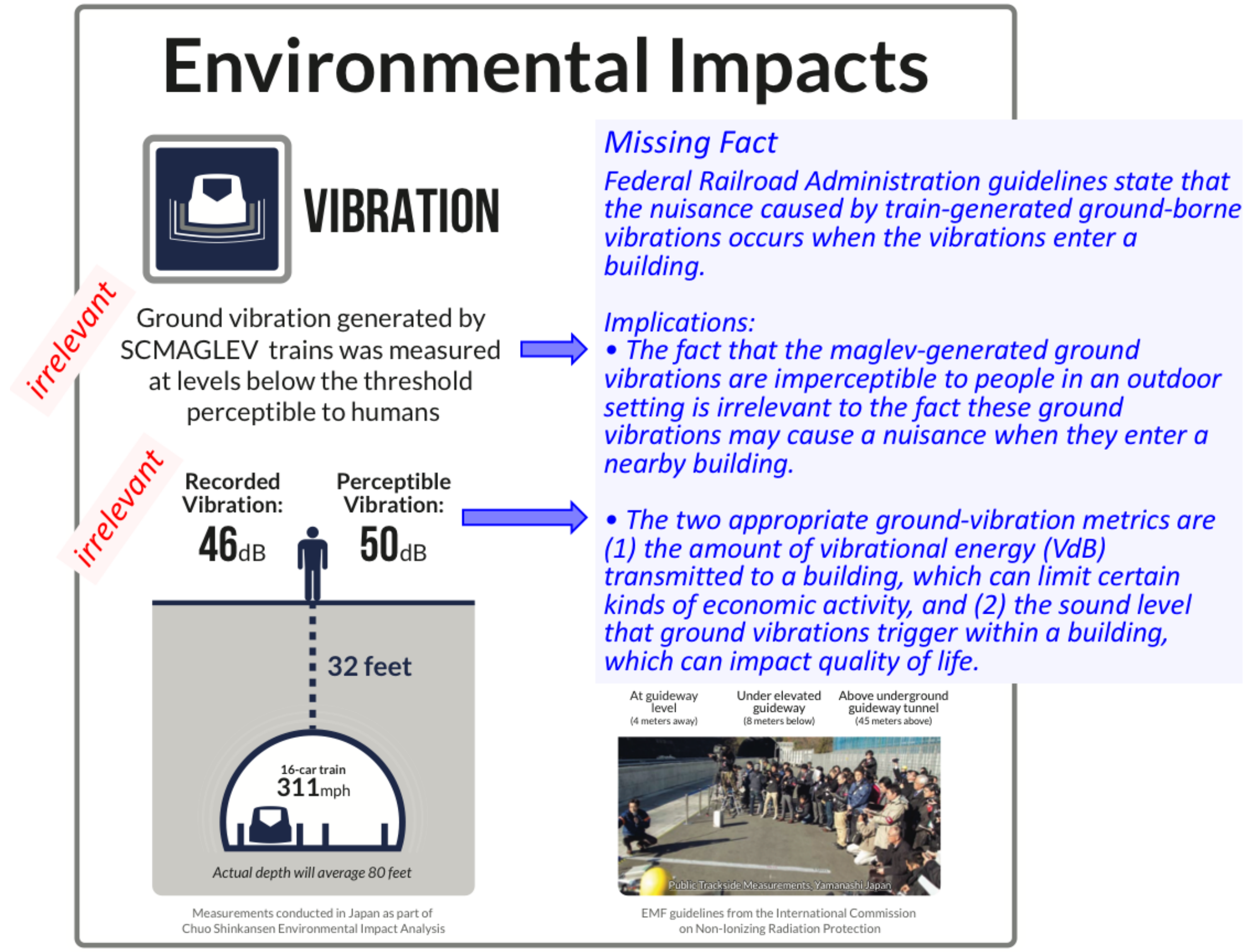


Figure 7. A poster board displayed at a public meeting hosted by the environmental impact study in the fall of 2017. The poster presents information related to the ground-vibration nuisance that would be generated by the proposed Baltimore-Washington superconducting maglev train (black text). The present text adds commentary in red and blue italicized text.

The poster board shown in Figure 7 states a misleading, yet quantitative, estimate of the maglev *vibration* nuisance, and furthermore, it fails to mention a relevant fact. Federal Railroad Administration guidelines (FRA 2012) state that high-speed trains can generated ground-borne vibrations that are imperceptible to humans in an outdoor setting, but which nonetheless can create a hazard when these ground vibrations enter a building. The poster board shown in Figure 7 gives a value for the wrong variable (i.e., the vibrational energy experienced outside), rather than providing values of the appropriate variables at various distances from the maglev track (i.e., the vibrational energy transmitted to a building and the ground-vibration-induced noise level inside of a building).

There are implications to the apparent low-quality of information that the parties to the Baltimore-Washington maglev environmental impact study have provided the public in relation to noise and vibration along the proposed maglev track. The low-quality of information recommends that one critically evaluate any numerical estimate of the geographic extent of noise and vibration nuisance that parties to the environmental impact study may publish in the future. Before accepting such estimates as accurate, complete, or reliable, it may be desirable to double-check each step of the related calculations that were performed by the environmental impact study. To do so, it might be necessary to hire a consulting engineer who is independent of the environmental impact study.

References

Federal Railroad Administration (FRA), 2012: *High-speed Ground Transportation Noise and Vibration Impact Assessment*, final report, September 2012. U.S. Department of Transportation, DOT/FRA/ORD-12/15, 248 pp. Available online at https://www.fra.dot.gov/eLib/details/L04090 .

Maryland Department Of Transportation (MDOT), 2003: *Baltimore-Washington Maglev Project, Draft Environmental Impact Statement and Section 4(f) Evaluation*, volume 1, October 2003. Available online at http://books.google.com .

Maryland Department Of Transportation (MDOT), 2017: Baltimore-Washington superconducting maglev project environmental study, web site. Available online at http://www.bwmaglev.info/ .

Morris, C., 2004: Two performance parameters-When acceleration is more important than speed in modern ground transportation systems. conference paper, 18th International Conference on Magnetically Levitated Systems and Linear Drives, Shanghai, China. Available online at http://www.maglev.ir/eng/documents/papers/conferences/maglev2004/topic1/IMT_CP_M2004_T1_25.pdf .

TNEM, 2017: Public Outreach Boards, Marketing Materials section of the Media webpage of the website of The Northeast Maglev (TNEM) corporation. Environmental impacts are described on posters 8 and 9, which cover noise and vibration, respectively. Available online at http://northeastmaglev.com/wp-content/uploads/2017/02/TNEM-BWRR-Public-Meeting-Posters.pdf and http://northeastmaglev.com/media/ .

Wikipedia, 2017: SCMaglev. Available online at https://en.wikipedia.org/wiki/SCMaglev .