STATE OF VERMONT
PUBLIC SERVICE BOARD

Docket No. 7156

Petition of UPC Vermont Wind, LLC for a Certificate of Public Good pursuant to 30 V.S.A. § 248, authorizing it to construct a 52 MW wind electric generation facility, and associated transmission and interconnection facilities, in Sheffield and Sutton, Vermont, and operate the same	)))))))	Docket No. 7156

PREFILED TESTIMONY OF
PETER H. GULDBERG

ON BEHALF OF

UNIVERSAL HEALTH SERVICE, INC., UHS OF SUTTON, INC., AND
RIDGE PROTECTORS, INC.

Mr. Guldbêrg provides testimony on the noise-related effects of the project on aesthetics, air and water purity, and public health and safety pursuant to section 248(b)(5). Mr. Guldberg's testimony also considers the testimony provided by the Petitioner's witness, Mr. Christopher J. Bajdek.

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Q1. Please state your name and occupation.

A1. My name is Peter H. Guldberg. I am President of Tech Environmental, Inc. ("TEI"), which is an environmental consulting firm based in Waltham, Massachusetts. TEI specializes in, among other things, noise studies, sound level measurements and acoustic modeling.

Q2. Have you previously filed testimony in this proceeding?

A2. No.

Q3. What is the purpose of your prefiled testimony?

A3. I will provide testimony on those section 248 criteria that relate to aesthetics, air and water purity, and public health and safety (section 248(b)(5)). I have reviewed the testimony of Mr. Christopher J. Bajdek on behalf of UPC Vermont Wind, LLC. In my review, I noted many statements by Mr. Bajdek that are incorrect and unsubstantiated by fact. My testimony will rebut his claims and identify likely noise impacts that Mr. Bajdek has ignored, which will adversely affect aesthetics of the acoustic environment.

Q4. Please describe your professional background.

A4. I am an acoustic scientist with over 30 years of experience in the field. As President of Tech Environmental, I have conducted sound monitoring and acoustic modeling studies for a wide variety of sources including power plants, industrial facilities, and wind turbines. I have degrees in Mathematics and Atmospheric Science from the Massachusetts Institute of Technology and the University of Michigan, respectively. I am an Associate Member of the Institute of Noise Control Engineering, a member of the Acoustic Society of America, and a Certified Consulting Meteorologist. I have served as an expert witness on noise impacts before State and local regulatory boards. For example, I have testified before the Massachusetts Energy Facilities Siting Board for the Cape Wind Project (EFSB 02-2/DTE 02-53), before the Vermont Environmental Court for a Verizon telecommunications facility in Newport (VEC 203-11-03), and before the New York Department of Public Service for the repowering of the Astoria Generating Station (Case No. 00-F-1522). A copy of my CV is attached.

Q5. What are the principal deficiencies of the Mr. Bajdek's analysis?

A5. There are five major deficiencies in the noise analysis of the UPC Vermont Wind project:

1) The sound power data are incomplete, especially for low frequency sounds, and do not conform to International Standard IEC 61400-11 for wind turbine generator systems.

2) No impulsivity analysis was performed. Recent research reveals that low frequency modulated sound from wind farms at night are the most annoying audible sounds these installations produce. Mr. Bajdek failed to consider these impacts.

3) The noise criterion selected by Mr. Bajdek, a 24-hour averaged broad-band measure, does not address the types of audible noise from wind farms that people find most objectionable: audible tones and a rhythmic "beating" character of noise that often occurs in the evening.

4) The acoustic modeling of the project underestimates maximum sound levels.

5) The baseline sound level monitoring done for the project is inadequate and fails to reveal how low ambient sound levels are in inhabited areas near the project site during time periods when the wind farm would operate.

Q6: Are the sound power data presented in Mr. Bajdek's report complete?

A6: No, they are inadequate, and they do not conform to International Standard IEC 61400-11 for wind turbine generator systems. All major WTG manufacturers publish sound power test data in conformance with IEC 61400-11. In response to discovery request UHS/RPI:UPC1-21 and UHS/RPI:UPC2-27, Mr. Bajdek has failed to provide such fundamental test data for either the Gamesa G87 WTG or the comparable GE WTG that UPC has said they will use on this project.

Q7: Could you provide an example of fundamental test data that are missing?

A7: Yes. Discovery request UHS/RPI:UPC1-21 asked for "all acoustic emission test reports on the Gamesa G87 wind turbine generator, including 1/3-octave band sound power levels from 16 Hz to 16 kHz..." In response, Mr. Bajdek only provides a short document from Gamesa Eolica (CB-1) that contained no 1/3-octave band sound power information. In his report dated February 14, 2006 (UPC-CB-2, pages 35 and 36), Mr. Bajdek makes express reference to such data and indicates that he performed "a comparison of projected wind farm noise levels in 1/3-octave bands" to vibration criteria. However, from the modeling results (CB-10) it is apparent that Mr. Bajdek did not use actual test data but instead created 1/3-octave band data by merely dividing the sound energy for each whole octave band into three equal parts. As explained below, this is inappropriate because in these circumstances the relevant international standards require, among other things, that an actual examination of 1/3 or whole octave bands down to 20Hz be performed.

Q8: Please summarize the sound power information that is missing from the UPC noise report?

have these been done?

A8: The following three items are missing:

1) No narrow-band frequency analysis of the WTG was done, and no tonality analysis was performed, as required by International Standard IEC 61400-11. Those data are important as they identify the frequency and sound power of pure tones generated by the WTG, information that is essential to any tone audibility impact analysis.

2) Low frequency sound power data are completely missing from the report and analysis. The very limited sound power data shown in Figure 7 (page 21) of the report (UPC-CB-2) are only for whole octave bands and thus obscure the fine detail of tonal peaks in the spectrum of the WTG. Every WTG has tonal peaks. The limited data used by Mr. Bajdek exclude the most important part of the spectrum, namely frequencies below 31.5 Hz, where the bulk of the WTG sound energy is produced and where the greatest noise impacts may occur. Table 3 and Figure 7 in the report show that sound power (Lw) in dB (unweighted) increases steadily up to 119 dB (re 1 pW) at the 31.5 Hz band and reveal that

most of the sound energy is below the point where the data cut off. In short, the greatest potential for aesthetically unpleasant noise exists at low frequencies below the point where Mr. Bajdek stopped his analysis. A proper low-frequency analysis would present 1/3-octave band sound power data down to 12.5 Hz to include some portion of the infrasound spectrum (frequencies below 20 Hz) where sound is not directly heard but often sensed by people as a rhythmic pressure oscillation. As discussed above, Mr. Bajdek did not work with actual 1/3-octave band sound power data.

3) Sound power data are only shown for a wind speed (at hub height) of 10 m/s. A proper assessment of impacts requires modeling the full range of WTG operation from the cut-in wind speed (3 m/s) to the cut-out wind speed (25 m/s). At the cut-in wind speed, ambient sound levels are low and WTG operation may have its greatest impact because sound masking is minimal. At the cut-out wind speed, high winds and a steep vertical wind profile enhance sound propagation through refraction in the atmosphere, causing WTG noise to travel further.

Q9: What is the effect of these missing data on the project's noise analysis?

A9: It means the project's noise analysis did not properly study the adverse impact of audible tones and low frequency noise on nearby residents, and did not model the worst-case operational conditions.

Q10: What types of noise are produced by a large WTG?

A10: There are three components to WTG noise: (1) Broadband aerodynamic sound caused by air flow around the blades; (2) Mechanical noise from the gearbox and generator that may contain discrete pure tones; and (3) Beating noise that is amplitude modulated, i.e., the sound pressure rises and falls with time at a rate that matches the blade passage frequency.

Q11: Which of these are addressed by the project's noise report?

A11: Only the first, broadband aerodynamic sound, which is the type of noise least likely to annoy people. The second and third kinds of noise, audible tones and impulse noise, were not analyzed. These two types of noise are also the impacts most likely to adversely effect public health and aesthetics.

Q12: Please describe the character of beating or impulse noise produced by a wind farm, noise that UPC did not study.

A12: For a single WTG, the impulse noise has a "swishing" sound with an oscillatory beat equal to the blade passage frequency (1 to 2 times per second). The amplitude modulation is most apparent in the well-audible range of sounds of 1,000-2,000 Hz where human hearing is most sensitive, and the cause is thought to be due to blade interaction with air turbulence around the tower or the variation in wind speed in the vertical space transversed by the blade.[1] When many WTGs are operated together in a wind farm, two or more of the individual turbines will, by chance, operate nearly synchronously for periods of time and the blade passage pulses accumulate into an audible beat. For example, Rhede Wind Park in Germany, which began operation in 2001, contains seventeen 1.8 MW turbines and is comparable in size to the proposed UPC project, which has twenty-six 2 MW turbines. Since the start of operation, residents living up to 2 km from the Rhede Wind Park have made complaints about the noise and have sued the operator in court. A research study done by the University of Groningen (Netherlands)[2] included detailed measurements in nearby residential areas and reached the following conclusions:

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[1] Eja Pedersen, "Noise annoyance from wind turbines – a review," Swedish Environmental Protection Agency Report 5308, August 2003, p. 9.

[2] G.P. van den Berg, "Effects of the wind profile at night on wind turbine noise," Journal of Sound and Vibration, 2004, pp. 955-970.

> On quiet nights the wind park can be heard at distances of up to several kilometers when the turbines rotate at high speed. On these nights, certainly at distances between 500 and 1,000 meters from the wind park, one can hear a low pitched thumping sound with a repetition rate of about once a second (coinciding with the frequency of blades passing a turbine mast), not unlike distant pile driving, superimposed on a constant broadband 'noisy' sound. A resident living at 1.5 km from the wind park describes the sound as 'an endless train.'[3]

* * * *

> At night the turbines cause a low pitched thumping sound superimposed on a broadband 'noisy' sound, the 'thumps' occurring at the rate at which blades pass a turbine tower. It appears that the characteristic, but usually small 'swishing' pulses . . . coincide because turbines operate nearly synchronously. Two coinciding pulse trains thus give a 3 dB higher pulse level, three a 5 dB pulse level. The measured pulse levels and frequencies agree with values expected from nearly synchronous pulse trains generated by a small number of wind turbines.[4]

Van den Berg[5] has demonstrated that the pulsing noise <u>generated</u> by a modern WTG increases by several decibels at night when the atmosphere is stable because of a greater difference in wind speed experienced at the top and bottom of the turbine blade's rotational cycle (a steeper wind speed gradient) and because of reduced air turbulence allowing nearby WTGs to spin at identical rotational speeds and synchronize. The noise is also more <u>audible</u> at night because of the lower background sound levels.

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[3] Ibid, p. 957.

[4] Ibid, p. 969.

[5] G.P. van den Berg, "The Beat is Getting Stronger: The Effect of Atmospheric Stability on Low Frequency Modulated Sound of Wind Turbines," <u>Journal of Low Frequency Noise, Vibration and Active Control</u>, 2005, pp. 4-6.

Detailed sound pressure level measurements at a residence 1 km from the WTGs shows broadband sound variations were substantial, 4 to 6 dB, with pulses matching the blade passage frequency.[6]

Given the similarities between the Rhede Wind Park and the UPC wind project, both in terms of WTG size and numbers of turbines, it is likely that highly-annoying impulse noise (described as a rhythmic thump described as distant pile driving) will be audible in the evening at the sensitive receptors within 2 km of the turbines, which include the King George School and many residences. This impulse noise would substantially impact public health and aesthetics in the very quiet rural area where the UPC wind park is proposed.

Q13: Does Mr. Bajdek's work take into account the work of G.P. van den Berg?

A13: No. In his response to Q.UHS/RPI:UPC2-19, Mr. Bajdek stated that the HMMH study "did not take into account the work of G.P. van den Berg" and indicated that he was unaware of the work at the time he performed his work for UPC.

Q14: Are there other aspects of Mr. Bajdek's analysis that are flawed?

A14: Yes. International standard IEC 61400-11 states that received sound levels have a low frequency component when the difference in dBC (used to measure sound sources with a dominant low frequency spectrum) and dBA (which roughly duplicates the hearing response of the human ear) exceeds 20 dB. The data produced by Mr. Bajdek clearly shows, see CB-10 (Excel document "Results_122005"), that for nearly all the sites measured, the difference between dBC and dBA exceeded 20dB.

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[6] G.P. van den Berg, "The Beat is Getting Stronger: The Effect of Atmospheric Stability on Low Frequency Modulated Sound of Wind Turbines," Journal of Low Frequency Noise, Vibration and Active Control, 2005, p. 12.

Q15: What does IEC 61400 require if the difference exceeds 20 dB?

A15: If the difference exceeds 20dB, the international standard calls for an examination of 1/3 or whole octave bands down to 20Hz and it also requires the analysis of narrow band spectra for frequencies below 100Hz down to 20 Hz to determine the low-frequency noise produced by the wind turbine .

Q16: Did Mr. Bajdek perform that low frequency analysis correctly?

A16: No. Mr. Badjek failed to analyze any narrow-band spectra for audible low frequency tones, and the analysis he presents in his report using 1/3-octave band levels does not extend down to 20 Hz and most importantly it utilized fictitious sound power data that are incapable of revealing whether the proposed wind turbine would create a low frequency noise problem. Mr. Bajdek did not use actual 1/3-octave band data, but instead created 1/3-octave bands by merely dividing the sound energy for each whole octave band into three equal parts.

Q17: Is this an accepted practice?

A17: No. It is not recommended in IEC 61400-11 or any standard guidance document in the acoustic consulting profession. By creating fictitious 1/3-octave bands that are flat across three bands and which do not represent the true tonal peaks of the wind turbine, Mr. Badjek has hidden the true low-frequency noise impacts of the project.

have they?

Q18: What should have been done to comply with IEC 61400-11?

A18: Actual 1/3-octave band sound power data for the Gamesa G87-2MW turbine covering the 20, 25, 31, 40, 50 and 63 bands should have been input to the acoustic model to predict the true 1/3-octave band sound level spectrum at each sensitive receptor. In addition, the narrow band spectra for frequencies from 20 Hz to 100 Hz with a bandwidth not exceeding 0.5 Hz should have been analyzed. These requirements are clearly stated in Sections 4.2.2.3 and A.3 of IEC 61400-11

Q19: You cite as the third major deficiency in the UPC noise analysis that the noise criterion selected by Mr. Bajdek does not address the types of noise from wind farms that people find most objectionable: audible tones and the rhythmic impulse noise or "beating" that can be heard in the evening hours. Please explain what Mr. Bajdek should have done in each instance.

A19: A proper analysis of <u>audible tones</u> would start with the narrow-band sound power spectrum and an identification of pure tones from the WTG that could be audible when ambient sound levels are low. The lowest measured ambient sound levels in each 1/3-octave band, from a long-term monitoring study, would then be added to the wind farm noise in each 1/3-octave band and compared to the ambient level in each band to determine whether the wind farm would create an <u>audible</u> tone. The audibility analysis presented in the noise report (UPC-CB-2, pp 34-35) did not follow this approach and reaches conclusions unsupported by facts. First, as discussed earlier, narrow-band sound power data were not obtained for the proposed 2 MW turbine and tonality in the frequency spectrum was not analyzed. In Figure 10 of the noise report, Mr. Bajdek presents wind farm sound level predictions alongside background noise levels measured at three sites. The comparison is deceptive for three reasons:

1) Mr. Bajdek did not add the wind farm noise to the background levels and compare the total future sound levels to existing backgrounds levels. By failing to properly calculate future sound levels, project impacts are underestimated.

2) The background sound data include measurements from the high-noise station M4 and thus do not represent the very low ambient sound levels at most of the sensitive receptors. As a result, project impacts are underestimated.

3) No low-frequency impacts for the project (sound below 31.5 Hz) are presented.

Q20: Are there other conclusions in this section that are incorrect and/or unsubstantiated?

A20: Yes. Three conclusions in this section of the noise report are incorrect and unsubstantiated by fact:

The conclusion (1st paragraph of page 34): "ambient wind noise will also mask the wind farm under certain conditions, such as during periods of high wind speeds" has no foundation. The authors did not perform acoustic modeling for a high wind speed condition. In fact, on page 30, they admit no attempt was made to quantify masking in their study.

The conclusion (3rd paragraph of page 34): "The graph of Figure 10 also illustrates that wind farm noise is 'broadband' in nature, that is, there are no peaks in the spectra, illustrating that the wind turbines would not produce audible tones" is completely unsubstantiated. First, Figure 10 does not present frequency spectrum results at a level of detail (1/3-octave band) that could even detect a "peak in the spectra," nor does it cover the important low-frequency range. Second, any claim of inaudibility must rest on masking by ambient noise, and the authors readily admit no such analysis was done.

The conclusion (top of page 35): "the wind farm . . . sound characteristics are similar to that of the background and are expected to blend well in the existing acoustic environment" has no factual foundation. To "blend well into the existing acoustic environment," a wind farm would need to have a frequency spectrum similar to that of the existing rural environment. Figure 10 in the noise report reveals that it does not; the wind turbine noise has a strong low-frequency component and as previously discussed the wind farm would likely produce annoying impulse noise out of character with the existing quiet rural environment.

Q21: What would a proper study of impulsive noise entail?

A21: A proper analysis of <u>impulse noise</u> would start with measurements of the time varying characteristics of audible noise from the proposed WTG, e.g., tests at an existing wind farm that utilizes the Gamesa G87 WTG or the equivalent GE model during nighttime temperature inversion conditions; or estimates using the measurement data from the Rhede Wind Park. The impulse noise from the wind park would then be compared to the lowest ambient sound level at sensitive receptors during nighttime conditions when the WTGs would operate to determine if impulse noise would be audible. No such analysis was done for the UPC project. has this been done.

Q22: Does the acoustic modeling of the project provide accurate estimates of the maximum noise impacts?

A22: No, the acoustic modeling underestimates maximum sound levels for three reasons. First, Mr. Bajdek's use of the "moderate downwind" condition in the ISO 9613-2 standard does not produce maximum sound levels from a wind farm and does not represent "worst case conditions" as Mr. Bajdek has testified (Bajdek Direct, page 3, line 20). What the ISO standard calls "moderate" winds are winds of 1 to 5 m/s (2 to 10 mph), more accurately termed light winds. The use of actual hub height wind speeds in the 10 to 25 m/s range in the acoustic model would result in higher predicted noise impacts. The existence of a vertical wind profile in the atmosphere (higher winds at the turbine blade height and low winds at ground level) causes sound waves to bend downward, an effect called refraction, in the downwind direction. Higher wind speeds produce a steeper vertical wind profile and greater refraction. The refraction effect in high winds increases the sound levels downwind of a wind farm over what would exist under lighter wind conditions. Acoustic modeling that our firm has done on another wind power project reveals that decibel contours stretch out toward downwind receptors as wind speed increases, if the model is told to use actual wind speed. In my opinion, using the ISO "moderate" wind assumption underestimates noise impacts by 2 to 3 dBA.

The second error in the UPC noise modeling was to assume sound attenuation by foliage (deciduous trees) when in fact there are no leaves on the trees six months of the year and sensitive receptors (including the residential buildings and open recreational areas at King George School) have a clear line of sight to where the WTGs would stand on the mountain ridges. In my opinion, this error underestimated noise impacts by 1 to 2 decibels.

The third modeling error by Mr. Bajdek was to assume special sound attenuation for ground absorption (UPC Response to Town of Sutton's First Set of Discovery Request, #61, page 29), which is inappropriate in uneven terrain and should not be used. The modeling methodology in ISO Standard 9613-2 used by Mr. Bajdek states in Section 7.3.1 that:

"This method of calculating the ground effect is applicable only to ground which is approximately flat, either horizontally or with a constant slope"[7]

The mountainous terrain around the UPC site does not satisfy these conditions and Mr. Bajdek's assumption of sound absorption by the ground per the ISO method underpredicted nose impacts by 2 to 3 dBA, in my opinion.

In sum, these three errors likely underestimate the sound level by 5 to 8 decibels, collectively. ? 6

Q23: Chapter 4 of the noise report states noise measurements were made at four locations to "characterize the existing noise environment in the vicinity of the wind farm." (CB-82, page 25). Are those data accurate and do they accomplish the stated goal?

A23: No. The baseline sound level monitoring done for the project is both inadequate and violates guidelines used by acoustic consultants. To illustrate this point, consider monitoring site M1 on Hardscrabble Road, southwest of King George School. Mr. Bajdek's company HMMH measured sound levels for less than two days, from 1:40 p.m. October 26, 2005 to 8:45 a.m. October 28 (CB-82, page 25). This short period of time is inadequate. In my experience, baseline sound level monitoring for a wind farm project is done for 1 to 2 weeks to ensure a broad range of meteorological conditions are covered. WCIS 14?

According to National Weather Service (NWS) records from the Burlington Airport (at a lower elevation and 55 miles to the west), there was a storm on October 26 with wind gusts over 30 mph and rain until 2 a.m. the following day. Up in the mountains of Caledonia County there was rain and snow, as evidenced by Figure 13 in the noise report.

[7] International Organization for Standardization, Standard ISO 9613-2, "Acoustics – Attenuation of Sound During Propagation Outdoors—Part 2: General Method of Calculation," 1996, page 5.

Not surprisingly, baseline sound levels at Station M1 during the first 24 hours of measurements were high due to the winds of the storm. NWS records show that while there was no precipitation after dawn on October 27 through to 8 a.m. on October 28, there were moderate winds of 6 to 15 mph during the day, which would elevate baseline sound levels. (Winds on the ridgelines where the WTGs would operate were presumably much higher than those measured at Burlington Airport). Only after 8 p.m. on October 27 do the winds subside.

The Acoustical Society of America has published an ANSI Standard for outdoor sound level measurements[8] that recommends no sound level measurements be made when the average wind velocity exceeds 5 m/s (11 mph) or during measurable precipitation. The reason for these restrictions is obvious: wind and precipitation impact a microphone creating noise. Using the best available hourly weather data from the nearest NWS station (Burlington), it can be concluded that about half of the baseline sound measurements are invalid because they fail to meet ANSI criteria. In addition, Figures 13 and 15 in the noise report clearly show snow accumulated on top of the microphone windscreen at Stations M1 and M2, which calls into the question the validity of <u>all</u> the measurements.

Q24: Did the measurements conducted by HMMH fail to capture other possible effects?

A24: Sound power data for the proposed Gamesa G87 WTG (CB-1, page 3) show the turbine operates in ridge-top winds (at 10 m) as light as 3 m/s. In mountainous terrain, temperature inversions often form at night in which cool, stable air pools at lower elevations (e.g., in and around the sensitive receptors for this project) and winds go calm.

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[8] Acoustical Society of America, "American National Standard S12.18-1994, Procedures for Outdoor Measurement of Sound Pressure Level," Section 4.4.1.

Existing sound levels are extremely low during these nighttime inversion conditions. At the same time, substantial winds may blow across the ridge tops at higher elevations above the inversion layer. Thus, the UPC wind project would operate under these nighttime inversion conditions producing noise impacts when ambient sound levels are very low. With the existence of such a temperature inversion, noise from the ridgeline would tend to be more audible because of the still air in the inversion layer at the sensitive receptors and because the stable atmosphere will refract sound waves downward toward the sensitive receptors. It is important, therefore, that baseline sound monitoring at locations such as monitoring station M1 be done for a sufficient length of time to capture several nights with temperature inversion conditions. HMMH has failed to do this and has failed to properly characterize the existing noise environment. Have they done this?

Q25: Mr. Bajdek has testified that the Project "will not have an undue adverse effect on public health or on aesthetics" (Bajdek Direct, page 2 line 18). Does the factual evidence he presents support that claim?

A25: No. The five major deficiencies discussed in detail above reveal that Mr. Bajdek has ignored the noise impacts of the Project that would be most damaging (pure tones, impulsive noise), has failed to provide complete sound power data for the project, has not modeled the worst-case condition, and has not documented the very low nighttime ambient sound levels in sensitive areas. In short, Mr. Bajdek has failed to demonstrate that the project will not have an undue adverse impact on public health or aesthetics.

Q26: Mr. Bajdek admits that the Project will be audible during nighttime periods with temperature inversions (UPC-CB-2, page 34). You have previously testified that a wind farm in Germany similar in size to the Project produces highly annoying impulse noise under these nighttime conditions at distances coincident with the location of many sensitive receptors near this Project. What conclusion do you draw?

A26: The UPC Project will likely create impulse noise at night that would adversely impact aesthetics in the very quiet rural area where there are homes and a boarding school for special-needs children (King George School).

Q27: Does this conclude your testimony?

A27: Yes.