Sound levels of helicopters used for administrative purposes at Grand Canyon National Park

Sarah Falzarano and Laura Levy
Overflights and Natural Soundscape Program
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INTRODUCTION

The large size and complex topography of Grand Canyon National Park (GCNP) presents a challenge to administrative activities requiring quick access or heavy loads. Further, the complex topography favors using more maneuverable helicopters over fixed-wing aircraft to accomplish administrative tasks. Administrative use of helicopters at GCNP supports fire management, maintenance, search and rescue, research, and other functions. In 2006, 667 hours were flown on helicopters contracted to the Park (NPS 2006). Most of the flights occurred on an MD-900 quiet technology helicopter in an effort to minimize noise impacts to Park resources. However, when the MD-900 is not available, a back-up helicopter (Bell 407) is used.

The MD-900 (Figure 1) is a twin-engine light helicopter equipped with a main overhead rotor and Boeing's no tail rotor (NOTAR) system, which eliminates the need for an exposed tail rotor. The NOTAR system consists of an enclosed variable-pitch fan driven by the main transmission, a circulation control tailboom, a direct jet thruster, and vertical stabilizers. It is designed to cut down on noise during overflight, but not necessarily during take-off and landing operations. The Bell 407 (Figure 2) is a single-engine turbine light helicopter. It uses a conventional tail rotor to control direction.

Figure 1. MD-900 used at Grand Canyon National Park.

Figure 2. Bell 407 used at Grand Canyon National Park.

METHODS

Location

On 4 April 2007, take-off and landing sound data of one flight of the MD-900 were measured at the South Rim helibase. The outbound and incoming overflight (level flyover) measurement occurred off of Rowe Well Road on the same day. Measurements of the Bell 407 occurred on 26 April 2007 during heli-rappel training. Because of the training, several (7-8) take-offs, landings, and hoverings were measured at the South Rim helibase. The overflight was measured at the Park dry dump site before the training. The Fire and Aviation Program operated equipment as it would typically be used. For take-off and landing, sound levels were measured 100 ft and 400 ft from the helipad to assess attenuation of noise with increasing distance from the sound source. Hovering during heli-rappel training occurred at an altitude of between 100 and 225 ft above ground level (AGL), and within 400 ft horizontally of the sound system. Only one system was used for overflight measurements, which occurred when the helicopter flew about 400 ft AGL (± 100 ft).

Sound Measurement Equipment

The sound system at 100 ft consisted of an ANSI Type 1 Larson-Davis sound level meter (model 824, powered by three AA batteries), a microphone (GRAS 40AE; protected by a Larson-Davis foam windscreen) and a preamplifier (Larson-Davis 902; Figure 3). The sound level meter and microphone were mounted on a tripod at a height of ~1.5 m, to mimic the average ear height of a person. The sound level meters collect sound pressure level data every second and are known to be accurate within 1 dBA. At the 400 ft and overflight sites, a Panasonic CF-18 Toughbook laptop (powered by a 12-volt battery) was added to the system to collect sample digital recordings. Recordings were collected for 60 seconds with 10-20 second intervals between recordings for the system to save the data to hard disk.

Figure 3. The sound system at 100 ft from the sound source. The sound level meter is taped to the top of the pelican case on the right of the tripod.

Acoustic Terms

Sound pressure level (L) – the logarithmic expression of sound pressure, or loudness; often reported in decibels (dB).
Frequency – the number of times per second that the wave of sound repeats itself; responsible for the pitch or tone of the sound; often expressed in cycles per second, or Hertz (Hz).
dBA – A-weighting de-emphasizes the high (6300 Hz and above) and low (below 1000 Hz) frequencies in an effort to simulate the relative response of human hearing.
L_{max} – maximum sound pressure level reported in decibels adjusted for human hearing, or dBA.
L_{eq} – energy equivalent sound pressure level; the level of a constant sound over a specific time period that has the same sound energy as the actual (unsteady) sound over the same period reported in dBA.
One-third octave band – a frequency band whose cut-off frequencies have a ratio of 2 to one-third (approximately 1.26); humans have the ability to differentiate one-third octaves.
Sound exposure level (SEL) – The total sound energy of an actual sound calculated for a specific time period. SEL is usually expressed using a time period of one second. This metric is useful in comparing two sounds that differ in amplitude and duration. A very long, very low level sound may have the same 1-second SEL as a very short, very loud sound.

Data Analysis

The L_{max} at the 100 ft site determined the time of the L_{max} value at the 400 ft site. This eliminated the potential for having a higher L_{max} at the further site when the helicopter may have come closer than the measured distance from the helipad during take-off, landing, or hovering. Where multiple measurements of the same operation type occurred (e.g., take-off of Bell 407), the maximum of the L_{max} values are reported.

RESULTS

Except for take-off measured at 100 ft from the helicopter, the MD-900 has consistently lower L_{max} values than the Bell 407 (Figure 4). At 400 ft, a 5.4 dBA difference between the MD-900 and Bell 407 is audible on take-off, but a much smaller difference is evident upon landing. However, differences between the quiet aircraft technology and traditional helicopter never exceed 5.4 dBA, which is a perceptible but not great difference in loudness. Because of the logarithmic scale of decibels, an increase in 10 dB sounds like a doubling in loudness (Everest 2001). The L_{max} for each one-third octave frequency band for take-off, landing, overflight, and hovering for the MD-900 and Bell 407 are listed in the Appendix.

The attenuation of aircraft noise is significant from 100 ft to 400 ft. Sound pressure levels quickly drop off with distance, greater than the 6 dBA with doubling of distance estimated by the inverse distance formula for point sound sources in a free field environment (Everest 2001). In fact, the average drop-off of 17 dBA between 100 and 400 ft suggests an 8.5 dBA drop-off with doubling of distance.

Comparison of the MD-900 and Bell 407 overflight frequency spectra (Figure 5) show the MD-900 having consistently lower sound pressure levels in the 50 to 1000 Hz range. While, the MD-900 has *higher* sound pressure levels below 50 and above 1000 Hz, the summation of the sound pressure levels into an overall L_{max} sound pressure level shows the MD-900 to be 4.4 dBA below the Bell 407. While this is a perceptible difference, it is not a great difference in loudness.

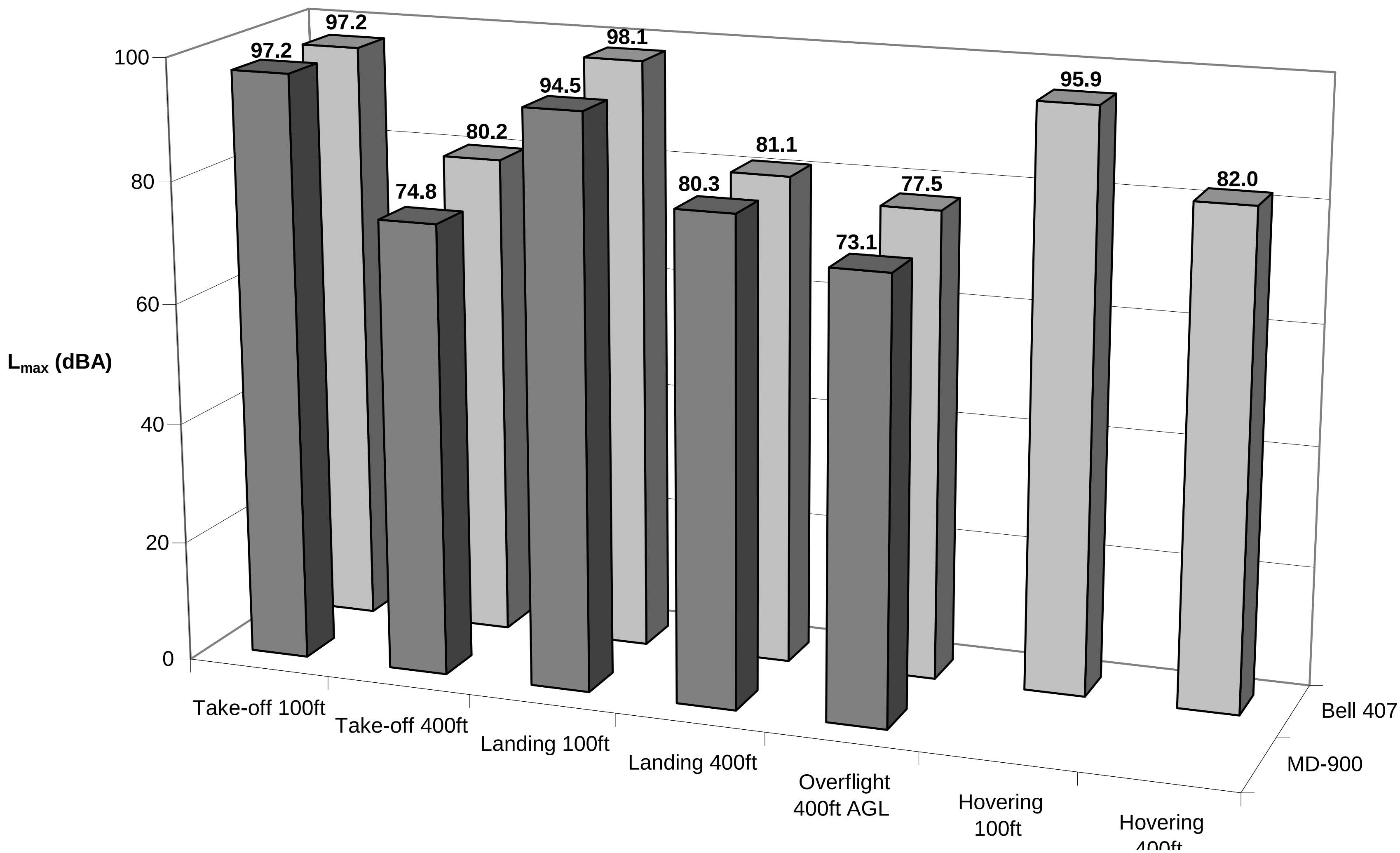

Figure 4. L_{max} levels (in dBA) of the MD-900 and Bell 407 for takeoff, landing, overflight, and hovering.

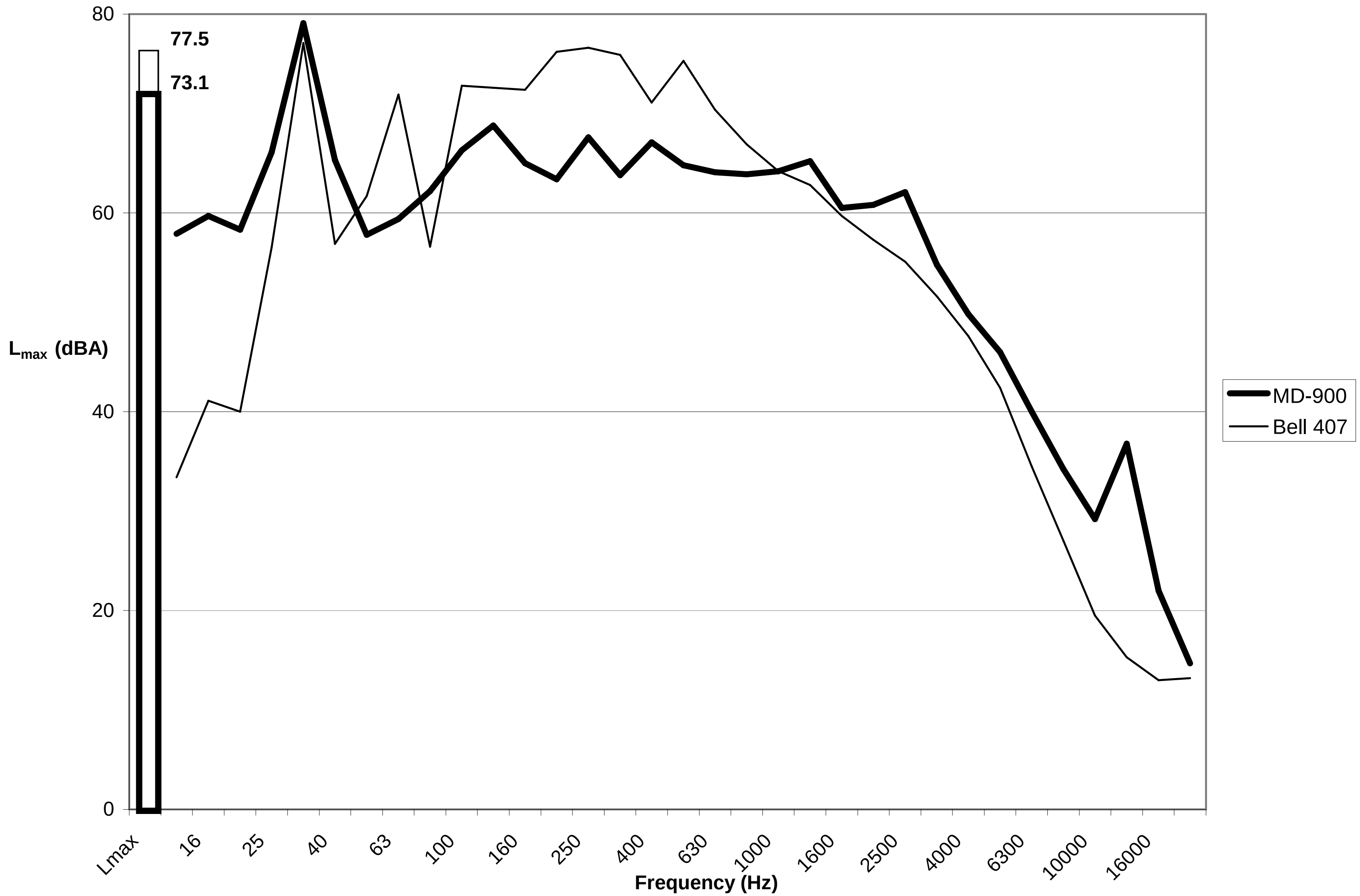

Figure 5. Helicopter frequency spectra for overflight at 400 ft AGL.

In an effort to quantify the noise produced by aircraft operations over Grand Canyon National Park, noise modeling is used. In the Integrated Noise Model (INM) 6.2 (© FAA 2006), not all aircraft types are available in the database of noise spectra. Neither the MD-900 nor the Bell 407 are in INM, so substitutions are used to approximate sound levels generated by these aircraft in noise modeling scenarios. While the MD-900 uses two engines and the MD-600 utilizes a single engine, they both employ NOTAR technology (Table). It appears that the MD-600 is a suitable modeling substitution to make for MD-900 operations. The maximum sound pressure levels at 400 ft are very similar (Figure 6). However, the Aerospatiale AS350 may overpredict the noise levels made by a Bell 407 by 6 dBA at 400 ft. Other helicopters commonly used for tour operations over GCNP (Eurocopter 130 and Bell 206 Longranger) are slightly louder than the MD-900 and Bell 407 at 400 ft AGL.

Helicopter specification comparisons between the MD-900 and its substitution, the MD-600, and Bell 407 and its substitution, the Aerospatiale AS350, are presented in the Table. Comparisons among the frequency spectra of the measured and certified aircraft are presented in Figures 7-10.

Table. Helicopter specifications.

	MD-900[1]	**MD-600**[2]	**Bell 407**[3]	**AS350**[4]
Manufacturer	MD Helicopters International	MD Helicopters International	Bell Helicopter/ Textron	Aerospatiale/ Eurocopter Group
Number of blades on main rotor	5	6	4	3
Type of tail rotor	NOTAR	NOTAR	Conventional	Conventional
Max gross take-off weight (lb)	6500	4100	5000	4960
Number and type of engine(s)	2 Pratt and Whitney 206E	1 Allison 250-C47	1 Rolls-Royce 250-C47B	1 Turbomeca Arriel
Length w/rotor turning (ft)	38.8	35.9	41.8	42.5

[1] MD Helicopters. 2001. MD Explorer Technical Description.
[2] MD Helicopters. 2006. MD 600N Technical Description.
[3] Bell Helicopter/Textron. 2006. Bell 407 Product Specifications.
[4] Eurocopter. 2006? AS350 B2 Technical Data.

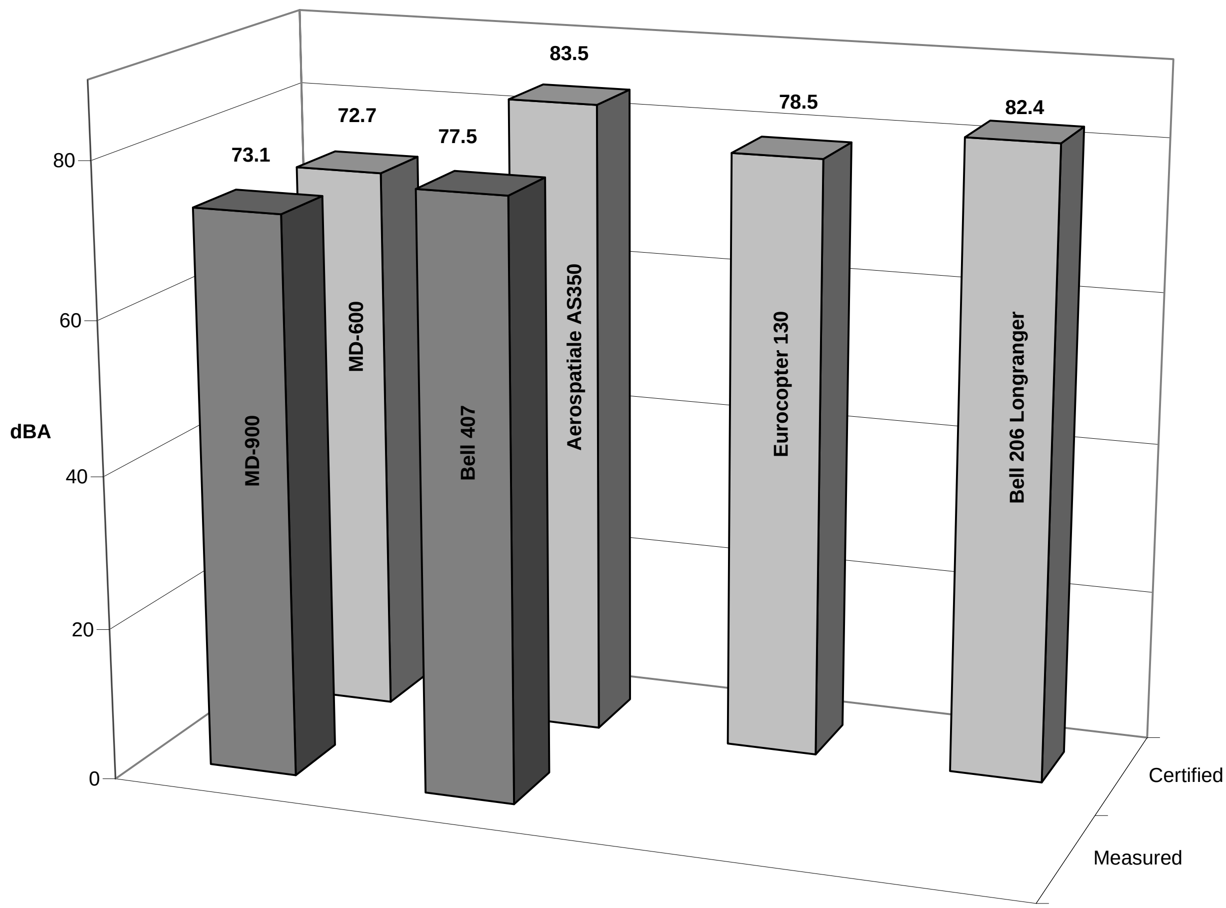

Figure 6. Measured and certified sound levels (L_{max} except for the Aerospatiale AS350 which is SEL) at a distance of 400 ft AGL for overflight. Certified data for the MD-900 and Bell 407 do not exist, but equivalent substitutions are the MD-600 and Aerospatiale AS350.

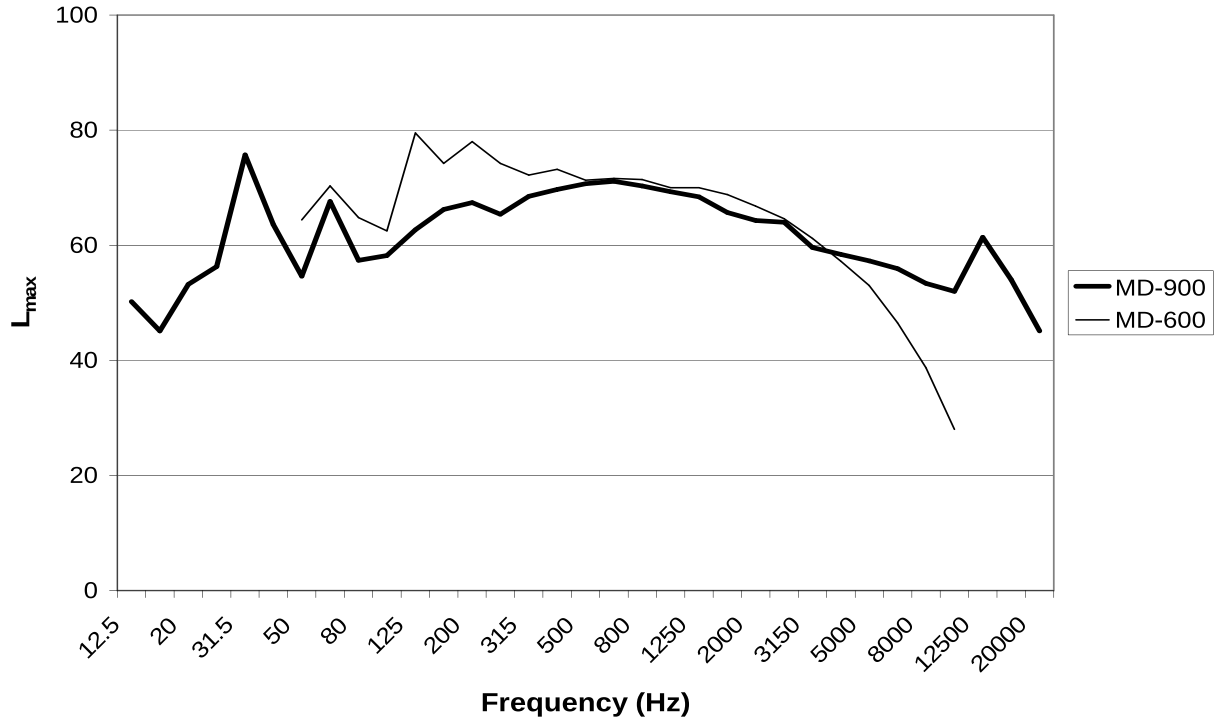

Figure 7. Comparison of measured MD-900 and certified MD-600 frequency spectra for take-off, normalized to 1000 ft.

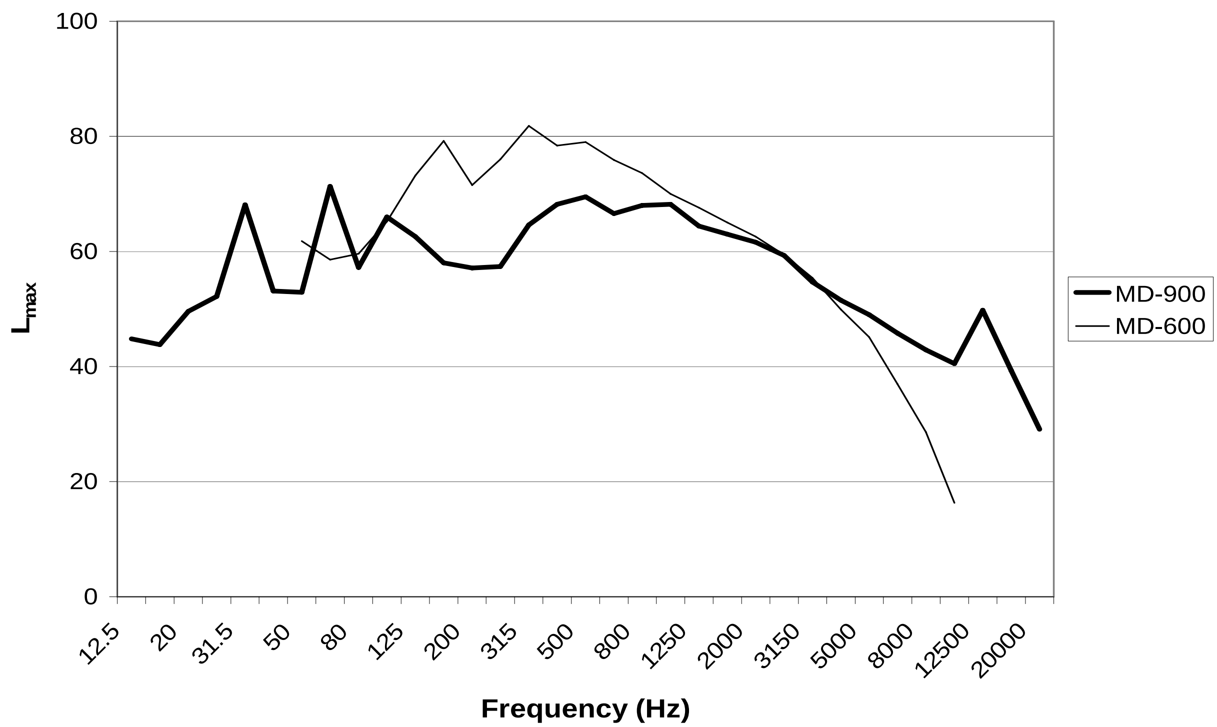

Figure 8. Comparison of measured MD-900 and certified MD-600 frequency spectra for landing, normalized to 1000 ft.

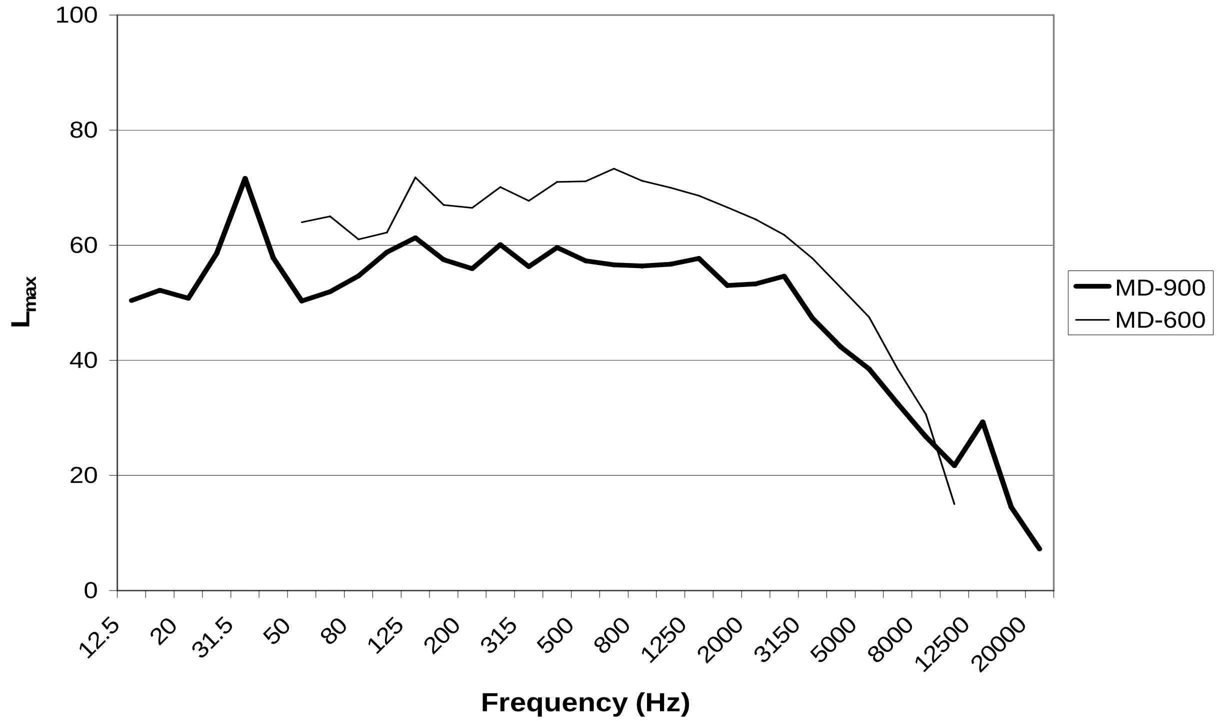

Figure 9. Comparison of measured MD-900 and certified MD-600 frequency spectra for overflight, normalized to 1000 ft.

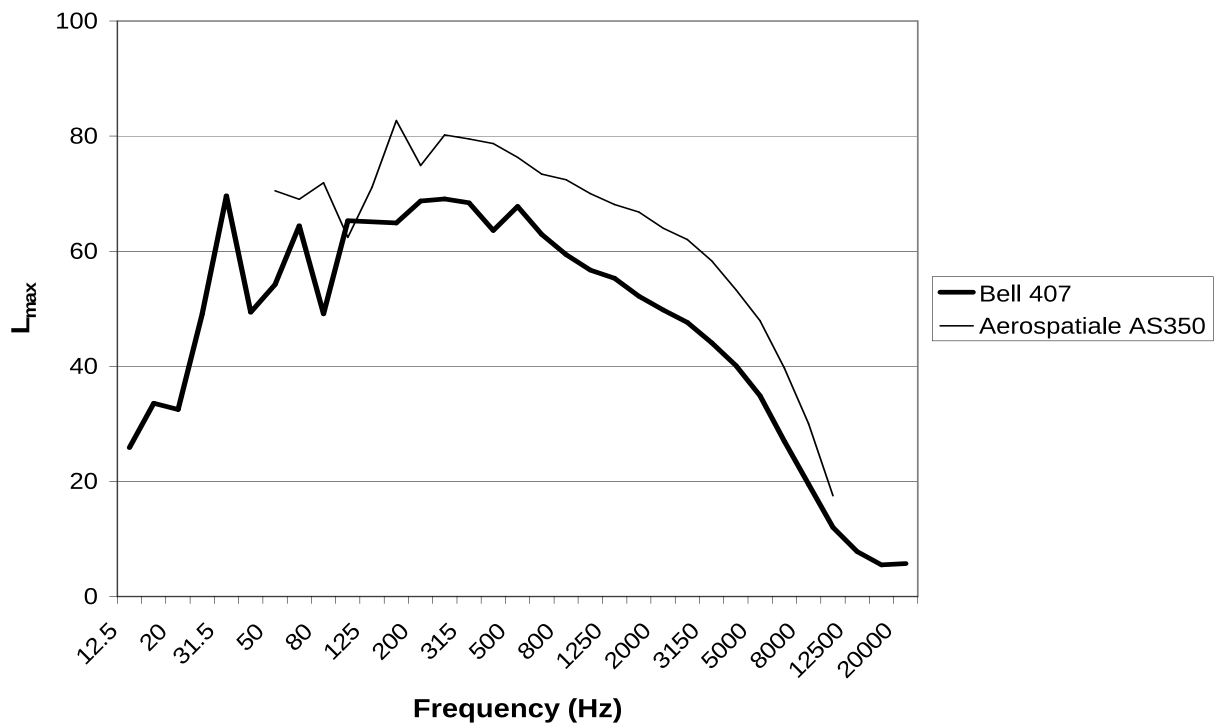

Figure 10. Comparison of measured Bell 407 and certified Aerospatiale AS350 frequency spectra for overflight, normalized to 1000 ft.

DISCUSSION

Measurements of GCNP helicopters were conducted with the best available technology and expertise available. However, full certification data uses many more microphones in an array, and takes many more measurements of the same activity (e.g., take-off, landing, and level overflight). One measurement of the MD-900 take-off and landing may not represent the average sound pressure level of that helicopter. In addition, accurate altitude data of the overflight was not available, and the altitude was approximated within ±100 ft. However, certified data may not represent the actual sound pressure levels in a given environment like GCNP. Therefore, these measurement data should be considered very specific to GCNP and not applied elsewhere.

ACKNOWLEDGEMENTS

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LITERATURE CITED

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NPS. 2006. Unpublished report on file. Grand Canyon National Park Fire & Aviation Year End Aviation Report 2006.

APPENDIX

MD900: L_{max} one-third octave band frequency sound pressure levels in dBA

Frequency	Take-off 100 ft	Landing 100 ft	Take-off 400 ft	Landing 400 ft	Overflight 400 ft AGL
dBA	97.2	94.5	74.8	80.3	73.1
12.5	69.7	64.3	50.9	57.6	57.9
16	64.6	63.3	47.9	54.7	59.7
20	72.7	69.1	51.4	56.4	58.3
25	75.8	71.7	51.3	56.0	66.1
31.5	95.2	87.6	75.3	83.2	79.1
40	83.1	72.6	59.4	66.2	65.3
50	74.1	72.4	56.5	58.9	57.8
63	87.1	90.8	67.5	77.9	59.4
80	76.9	76.7	59.4	66.0	62.2
100	77.7	85.5	65.6	75.3	66.3
125	82.2	82.1	61.7	69.1	68.8
160	85.7	77.5	61.1	69.3	65.0
200	86.9	76.6	62.6	69.2	63.4
250	84.9	76.9	58.4	69.8	67.6
315	88.0	84.1	57.9	70.1	63.8
400	89.2	87.7	56.0	68.2	67.1
500	90.2	89.0	58.2	70.9	64.8
630	90.6	86.1	62.6	73.0	64.1
800	89.8	87.5	66.2	73.9	63.9
1000	88.8	87.7	65.6	74.5	64.2
1250	87.9	83.9	69.4	71.1	65.2
1600	85.2	82.5	64.9	67.8	60.5
2000	83.8	81.1	63.1	66.6	60.8
2500	83.5	78.8	62.8	63.2	62.1
3150	79.1	74.2	57.4	58.3	54.8
4000	77.9	71.0	54.6	53.5	49.8
5000	76.8	68.5	51.1	48.9	46.0
6300	75.4	65.3	46.5	42.7	40.0
8000	72.9	62.4	41.5	36.9	34.2
10000	71.5	60.0	35.3	32.2	29.2
12500	80.9	69.3	34.0	31.7	36.8
16000	73.5	58.8	26.0	20.8	22.0
20000	64.6	48.6	15.5	15.9	14.7

Bell 407: L_{max} one-third octave band frequency sound pressure levels in dBA

Frequency	Take-off 100 ft	Landing 100 ft	Hovering 100 ft	Take-off 400 ft	Landing 400 ft	Hovering 400 ft	Overflight 400 ft AGL
dBA	97.2	98.1	95.9	73.1	78.5	82.0	77.5
12.5	72.7	60.8	79.3	59.3	44.0	57.4	33.4
16	68.6	64.5	67.6	56.2	45.5	52.6	41.1
20	78.1	67.9	67.6	54.1	48.2	52.4	40.0
25	89.3	96.8	86.3	79.1	79.1	84.5	56.5
31.5	86.6	95.9	84.2	76.2	72.8	81.1	77.1
40	75.5	72.8	67.7	53.5	55.3	57.7	56.9
50	83.9	83.2	81.9	72.8	75.6	79.7	61.7
63	80.8	81.5	78.3	69.6	69.0	75.8	71.9
80	93.1	89.6	78.2	78.9	78.6	77.9	56.6
100	82.6	84.2	82.8	64.4	63.9	68.0	72.8
125	81.6	88.8	86.4	64.2	63.0	64.2	72.6
160	82.7	97.6	91.7	72.5	76.3	73.4	72.4
200	83.7	86.3	92.7	65.9	72.9	66.5	76.2
250	83.6	96.1	86.7	66.0	72.8	72.1	76.6
315	81.8	87.8	94.8	59.9	65.9	76.0	75.9
400	86.4	90.8	89.2	63.7	64.2	73.9	71.1
500	91.4	89.9	90.4	64.0	66.9	74.1	75.3
630	93.5	89.9	88.3	66.3	69.8	73.6	70.4
800	92.4	91.6	87.9	66.4	70.3	75.1	66.9
1000	87.7	89.5	86.6	65.0	70.1	73.7	64.2
1250	83.8	87.8	84.7	63.5	70.7	72.4	62.8
1600	83.4	84.8	81.9	62.6	69.8	71.6	59.7
2000	81.5	83.2	79.6	59.2	66.2	70.1	57.3
2500	78.0	81.1	76.2	56.0	62.4	66.7	55.1
3150	74.2	78.5	72.1	52.3	58.5	62.8	51.6
4000	71.7	75.9	68.2	47.2	53.2	58.5	47.6
5000	68.9	73.0	64.3	43.0	48.0	53.1	42.4
6300	65.5	71.5	60.7	36.2	42.6	47.8	34.5
8000	61.8	74.6	57.9	29.4	37.6	42.3	27.0
10000	58.8	77.7	56.0	22.6	33.5	37.9	19.5
12500	57.3	81.2	55.5	17.6	33.4	34.2	15.3
16000	57.6	81.1	55.8	14.5	29.2	34.6	13.0
20000	53.3	76.7	49.4	13.6	15.7	21.5	13.2