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USAARL NUH-60FS Acoustic Characterization

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14. ABSTRACT The United States Army Aeromedical Research Laboratory (USAARL) Auditory Protection and Performance Division (APPD) previously acoustically characterized the Black Hawk flight simulator (NUH-60FS). Since that characterization, the NUH-60FS underwent upgrades and modifications, leading to the possibility that the previous characterization may no longer be accurate. Measurements of the NUH-60FS examined the base speakers and higher-level speakers at five different noise-level settings. The base speakers yielded lower levels across the third octave band levels from 31.5 Hertz (Hz) to 8000 Hz, while the higher-level speakers had some levels lower and some levels higher. For the pilot seats, research participants should wear hearing protection for levels greater than one with the base speakers and for all levels with the higher-level speakers while the flight simulator is in operation. For the two rear positions, the levels change to greater than three for the base speakers and greater than one for higher-level speakers.					
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Introduction

The United States Army Aeromedical Research Laboratory (USAARL) owns, maintains, and operates a Black Hawk flight simulator (NUH-60FS) for aeromedical research purposes. Figure 1 below shows the cockpit of the USAARL NUH-60FS and Figure 2 is a schematic of the seating positions in the flight simulator.



Figure 1. Cockpit of the U.S. Army Aeromedical Research Laboratory NUH-60FS Black Hawk Flight Simulator.

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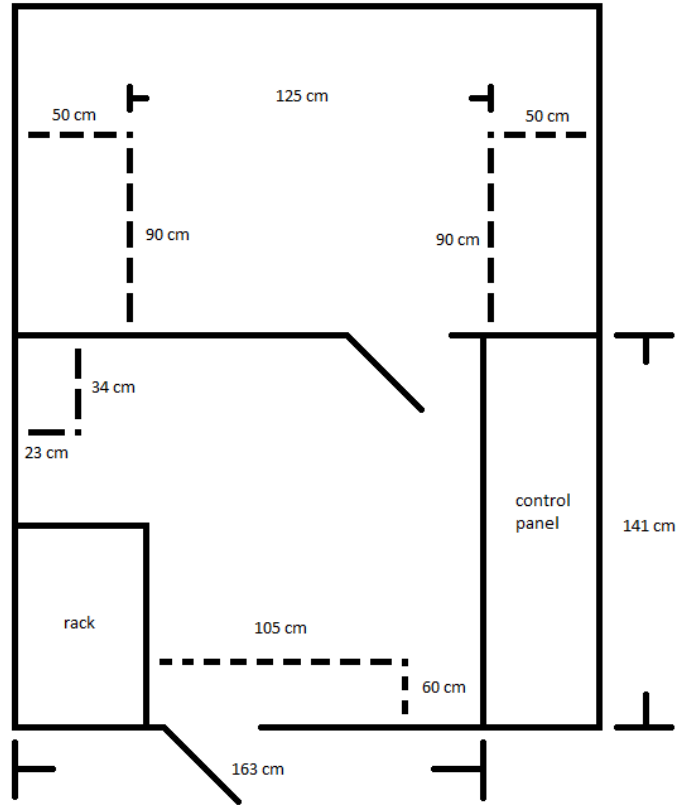


Figure 2. U.S. Army Aeromedical Research Laboratory NUH-60FS Seat Positions Schematic.

The USAARL Auditory Protection and Performance Division (APPD) previously studied the acoustic levels of the NUH-60FS. The Table below reproduces the data used for analysis of the previous testing (Gordon & Ahroon, 2000).

Table. Previous NUH-60FS Third Octave Band Levels (Right Pilot)

Setting	Third Octave Band Level (dB)									Overall (dBA)
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
1	67.2	78.8	84.6	90.7	75.5	69.6	66.1	60.1	58.4	81.8
3	68.0	85.9	91.9	98.0	82.6	75.4	67.6	60.4	62.9	88.9
5	68.9	90.8	96.9	103.4	87.6	80.0	69.9	61.1	67.8	94.0
7	69.3	93.3	99.4	106.3	90.8	83.2	72.6	62.3	72.3	97.0
9	70.0	94.8	101.0	108.0	92.5	85.3	74.9	64.1	74.8	98.8

The NUH-60FS has been upgraded since the previous characterization, and these upgrades may have affected the ambient noise levels. The ambient noise levels of the NUH-60FS while operating can be controlled via either software or hardware adjustments. The new data collected looked at the base speaker set as well as a speaker set capable of producing a higher noise level. Additionally, microphones placed at the observer and controller positions located behind the pilot seats in the flight simulator collected new data.

Methods

The acoustic characterization involved five noise levels adjustable via control console, as well as with two sets of speakers installed. While comparison with the previous characterization only examined five levels, data collection involved all possible noise levels. Measurements were obtained from two microphones hung from the left and right pilot seats and two microphones on stands at the controller and observer seats.

Materials

Two Brüel and Kjær 4192-L-001 microphones recorded data from the left and right pilot seats. An additional two Brüel and Kjær 4192 microphones connected to Brüel and Kjær 2669C preamplifiers recorded data from the simulator controller seat and the observer seat. The data acquisition device used was a Brüel and Kjær LAN-XI 3160-A-4/2 module and Brüel and Kjær PULSE Reflex software handled data processing.

Results

Left Pilot

Figures 3 through 7 present the third octave band levels of the five noise settings at the left pilot position for the previous measurements, the current base setup, and with different speakers installed. Figure 8 presents the overall A-weighted levels for all three setups at the five noise settings.

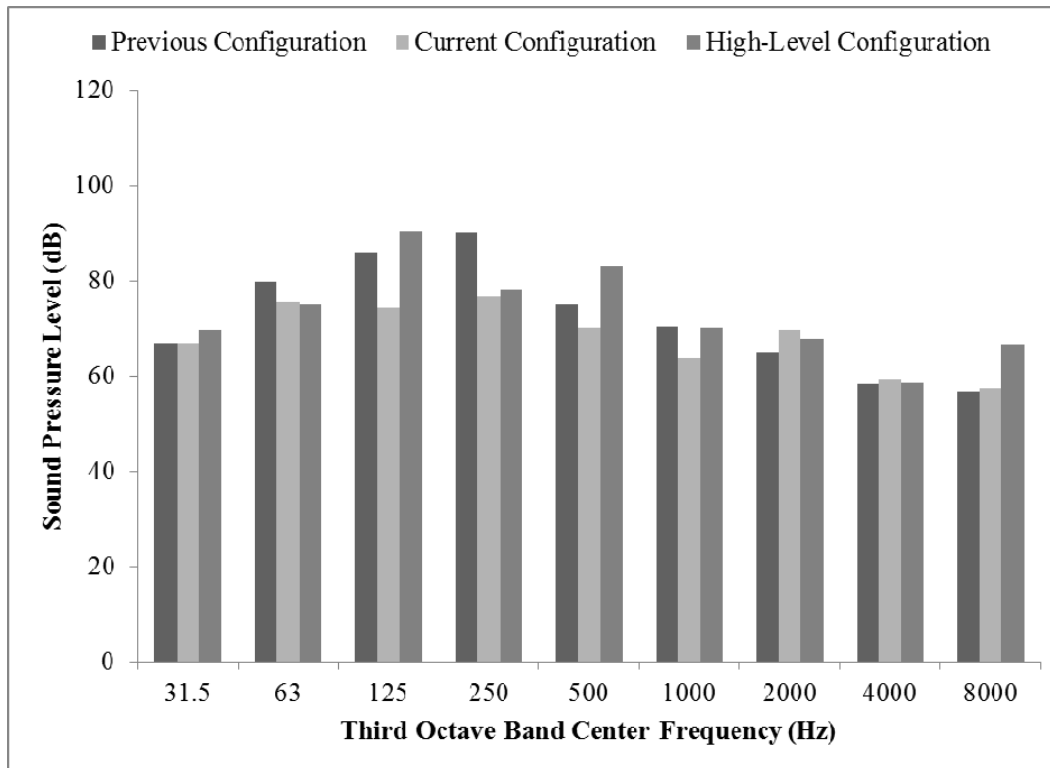


Figure 3. Left Pilot Third Octave Band Levels (Noise Setting 1).

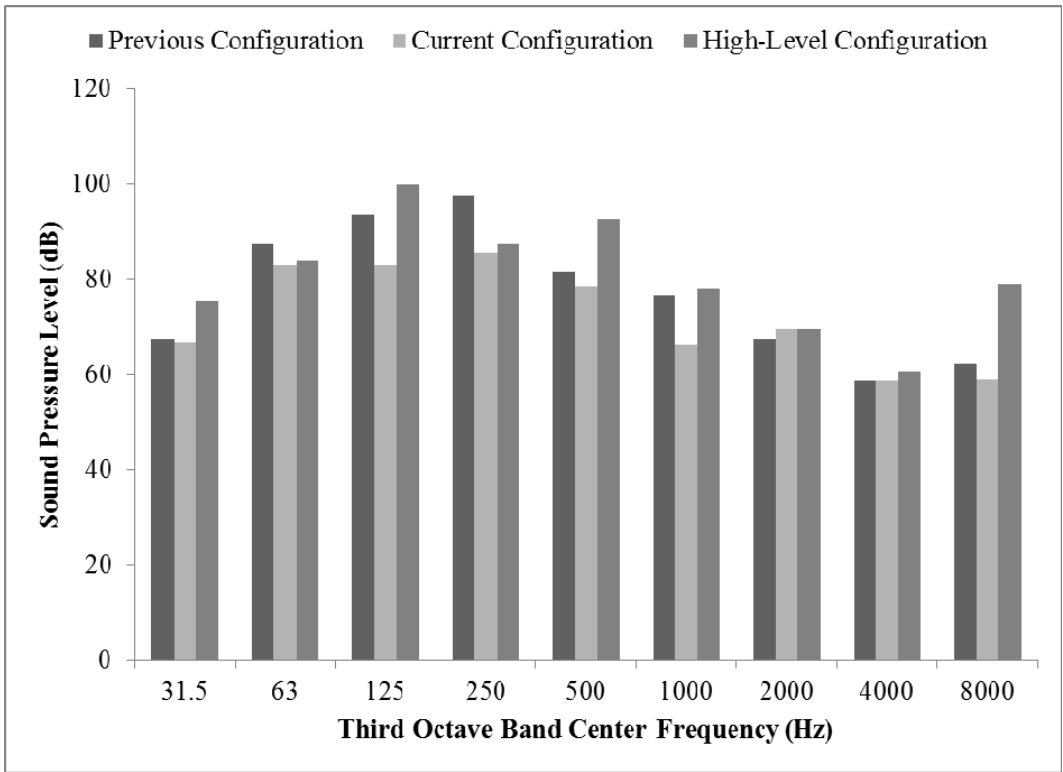


Figure 4. Left Pilot Third Octave Band Levels (Noise Setting 3).

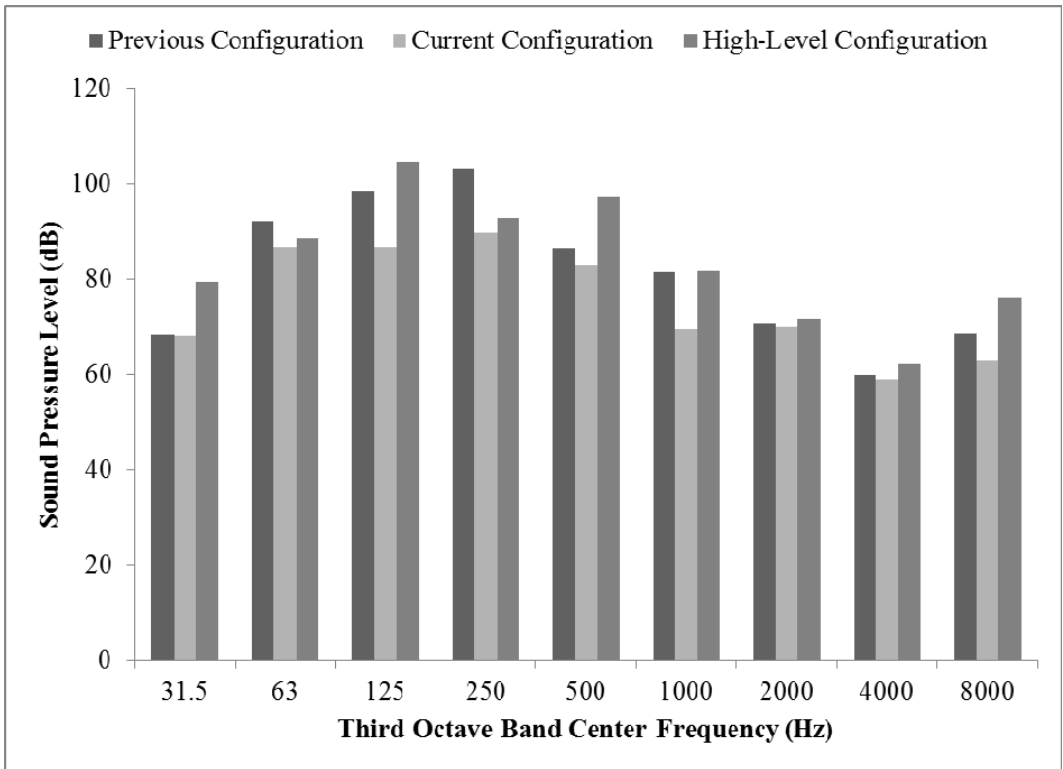


Figure 5. Left Pilot Third Octave Band Levels (Noise Setting 5).

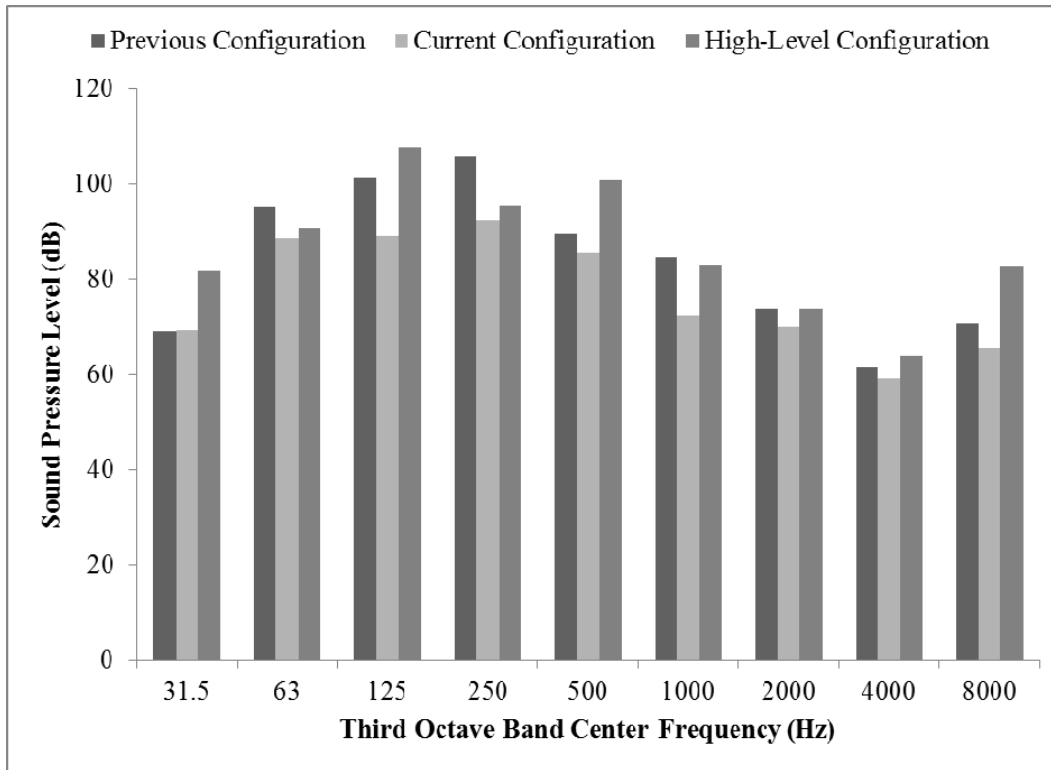


Figure 6. Left Pilot Third Octave Band Levels (Noise Setting 7).

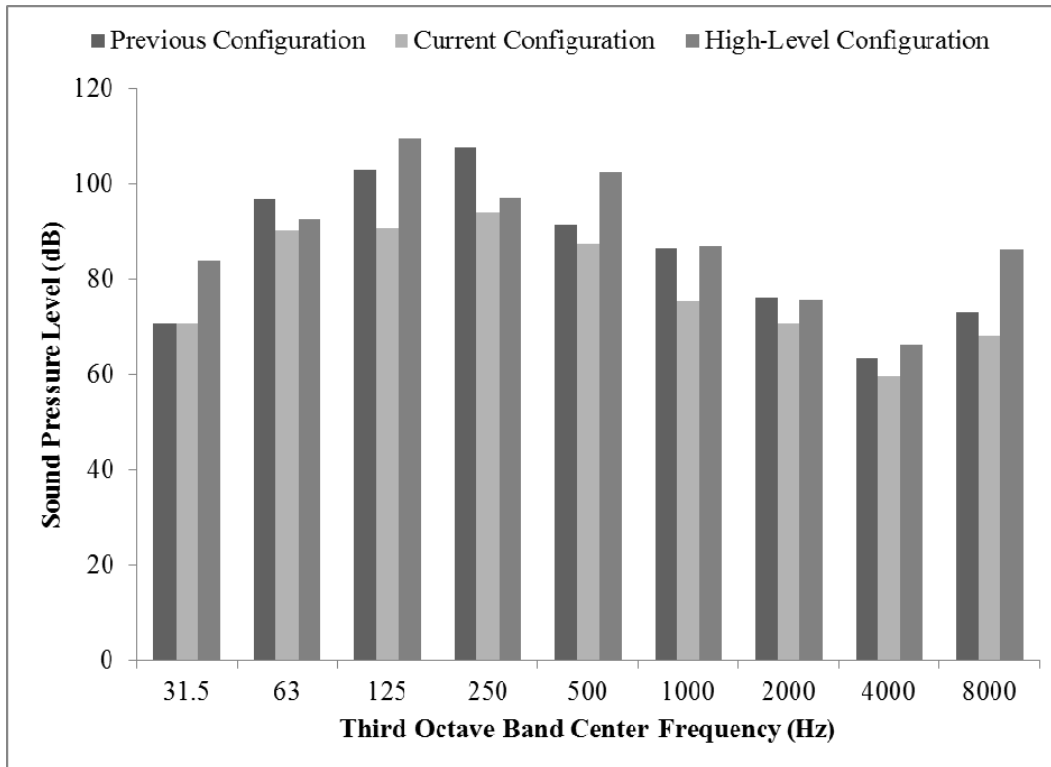


Figure 7. Left Pilot Third Octave Band Levels (Noise Setting 9).

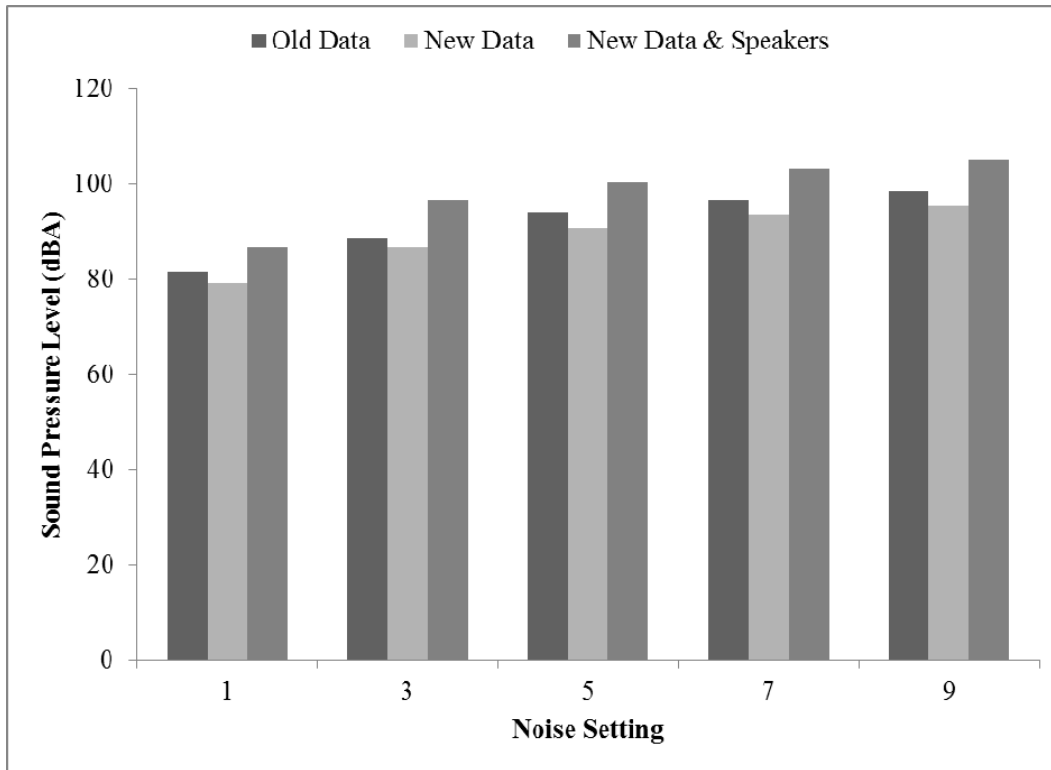


Figure 8. Left Pilot A-weighted Overall Levels.

Right Pilot

Figures 9 through 13 present the third octave band levels of the five noise settings at the right pilot position for the previous NUH-60FS measurements, the current base setup, and with different speakers installed. Figure 14 presents the overall A-weighted levels for each of the setups at the five noise settings.

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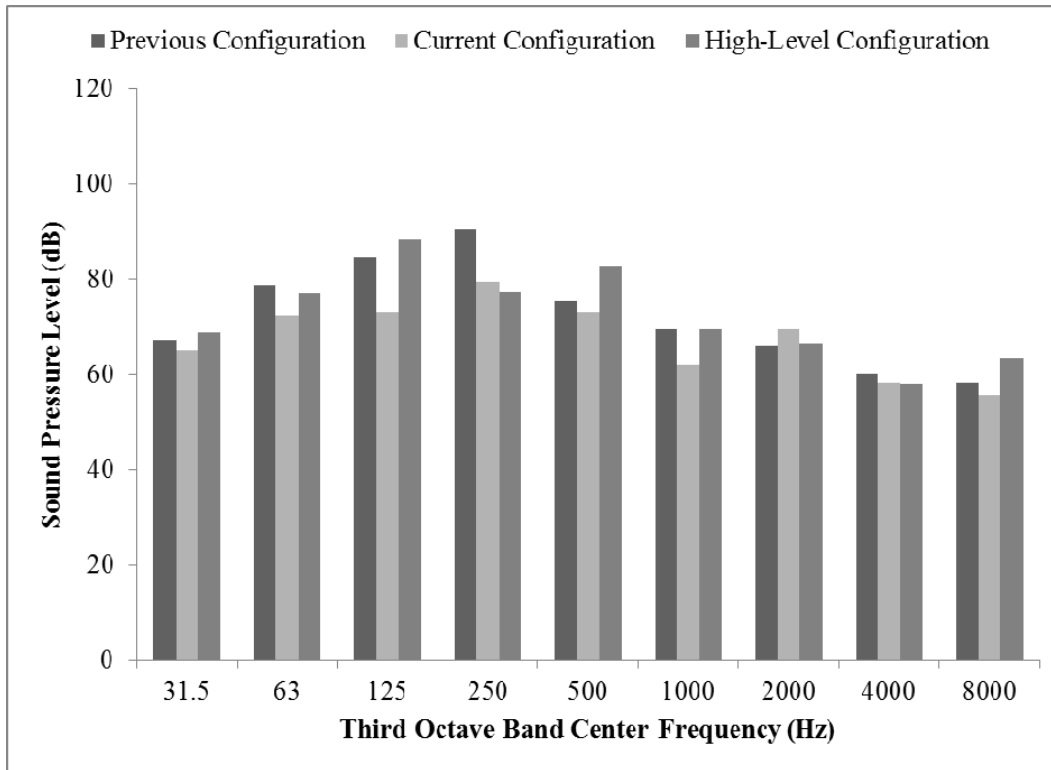


Figure 9. Right Pilot Third Octave Band Levels (Noise Setting 1).

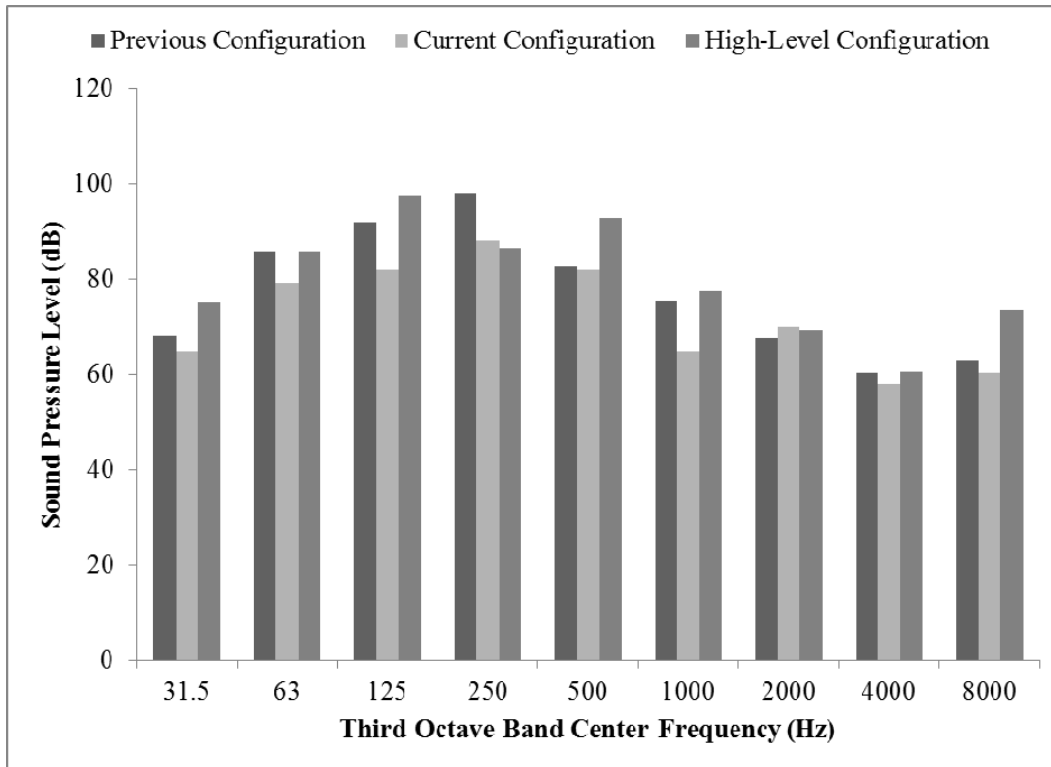


Figure 10. Right Pilot Third Octave Band Levels (Noise Setting 3).

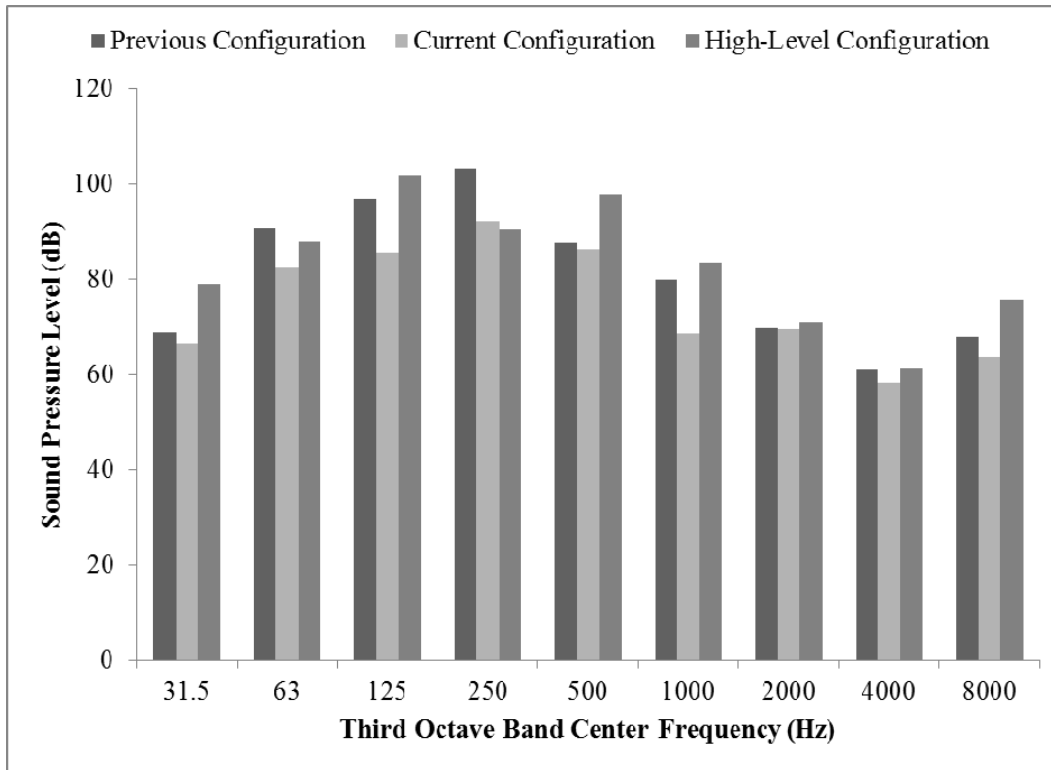


Figure 11. Right Pilot Third Octave Band Levels (Noise Setting 5).

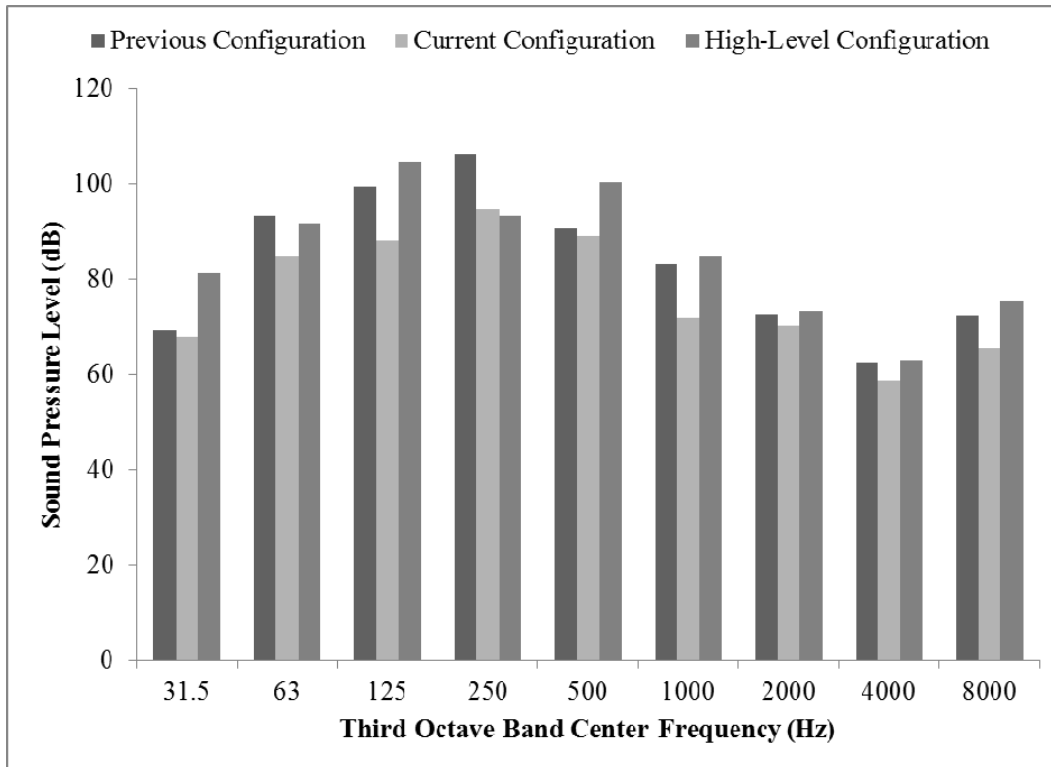


Figure 12. Right Pilot Third Octave Band Levels (Noise Setting 7).

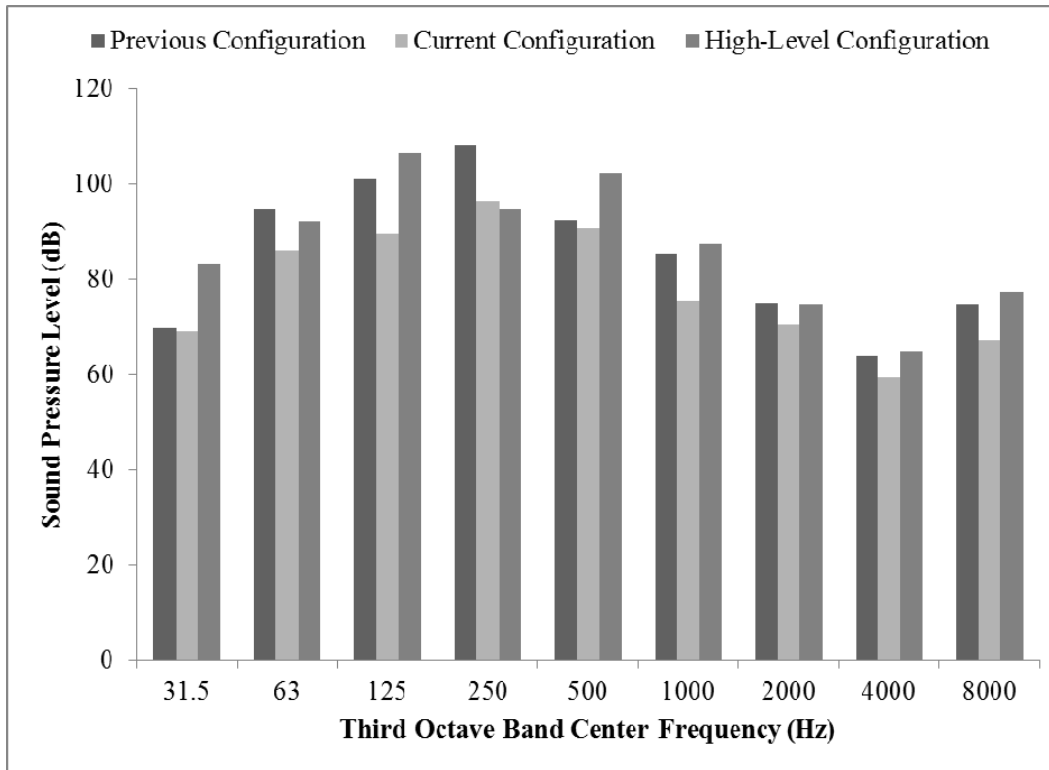


Figure 13. Right Pilot Third Octave Band Levels (Noise Setting 9).

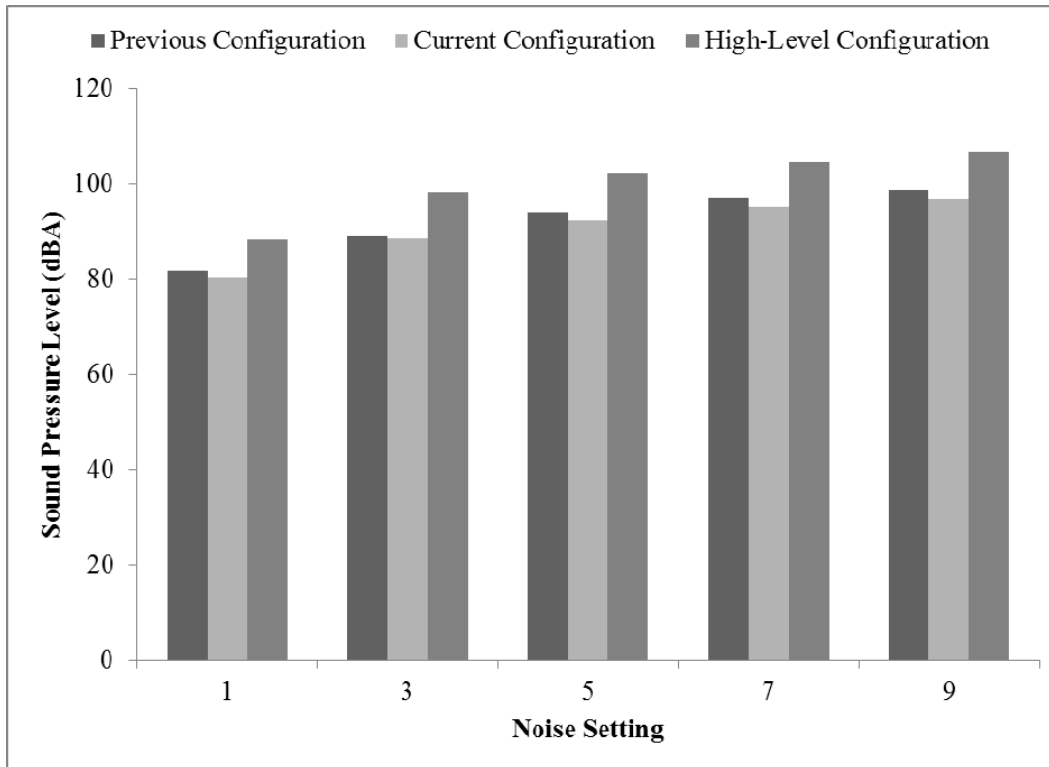


Figure 14. Right Pilot A-weighted Overall Levels.

Observer

Figures 15 through 19 present the third octave band levels of the five noise settings at the observer position for the current base setup and with different speakers installed. Figure 20 presents the overall A-weighted levels for both setups.

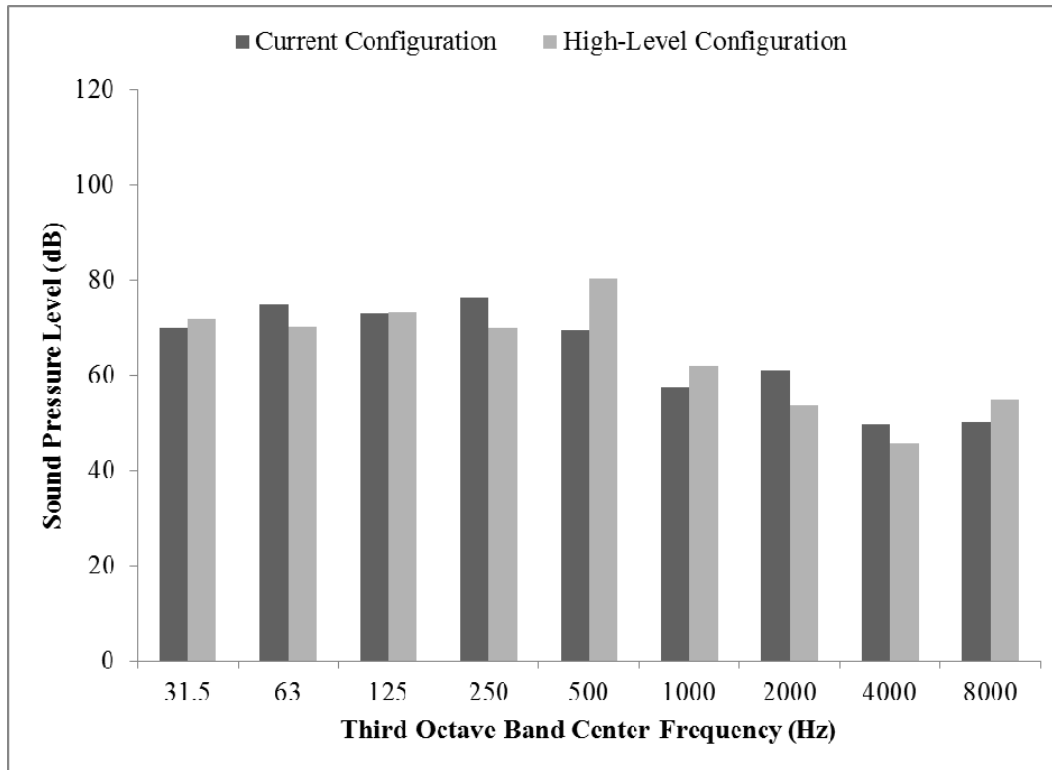


Figure 15. Observer Third Octave Band Levels (Noise Setting 1).

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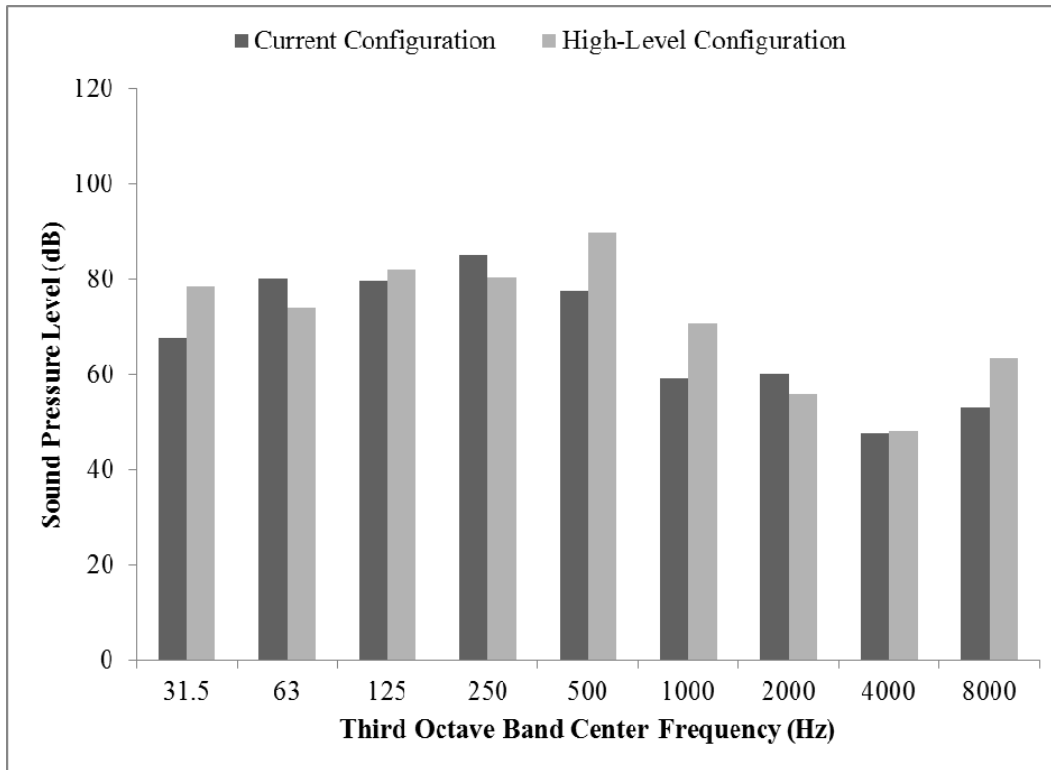


Figure 16. Observer Third Octave Band Levels (Noise Setting 3).

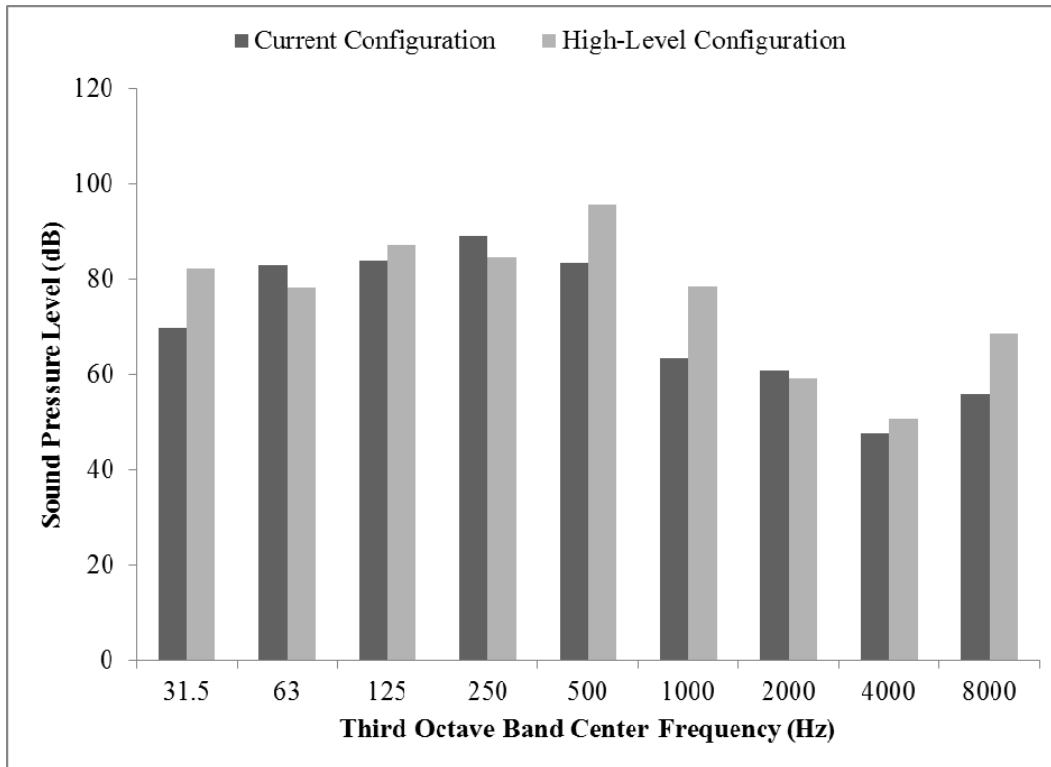


Figure 17. Observer Third Octave Band Levels (Noise Setting 5).

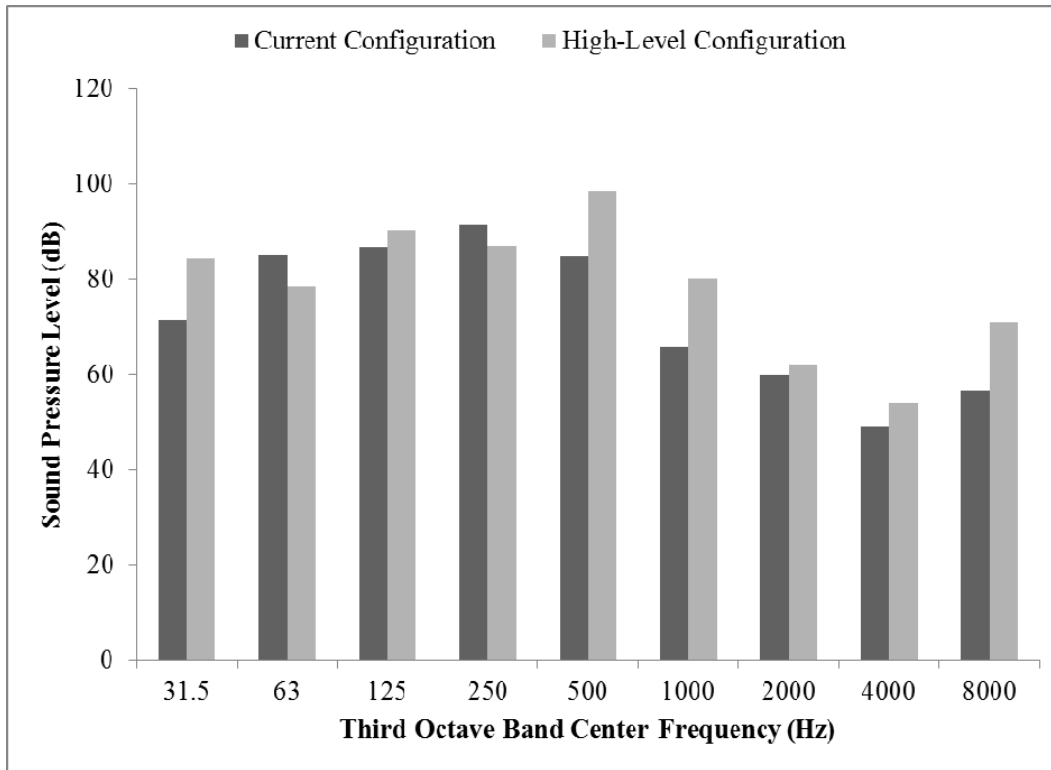


Figure 18. Observer Third Octave Band Levels (Noise Setting 7).

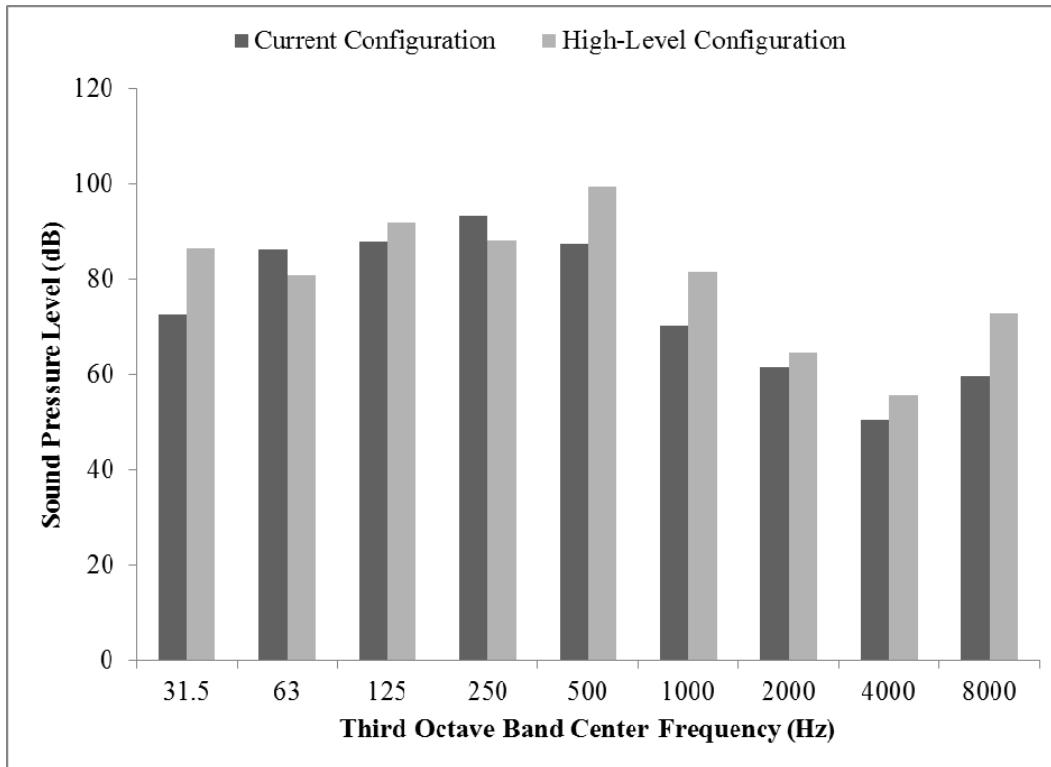


Figure 19. Observer Third Octave Band Levels (Noise Setting 9).

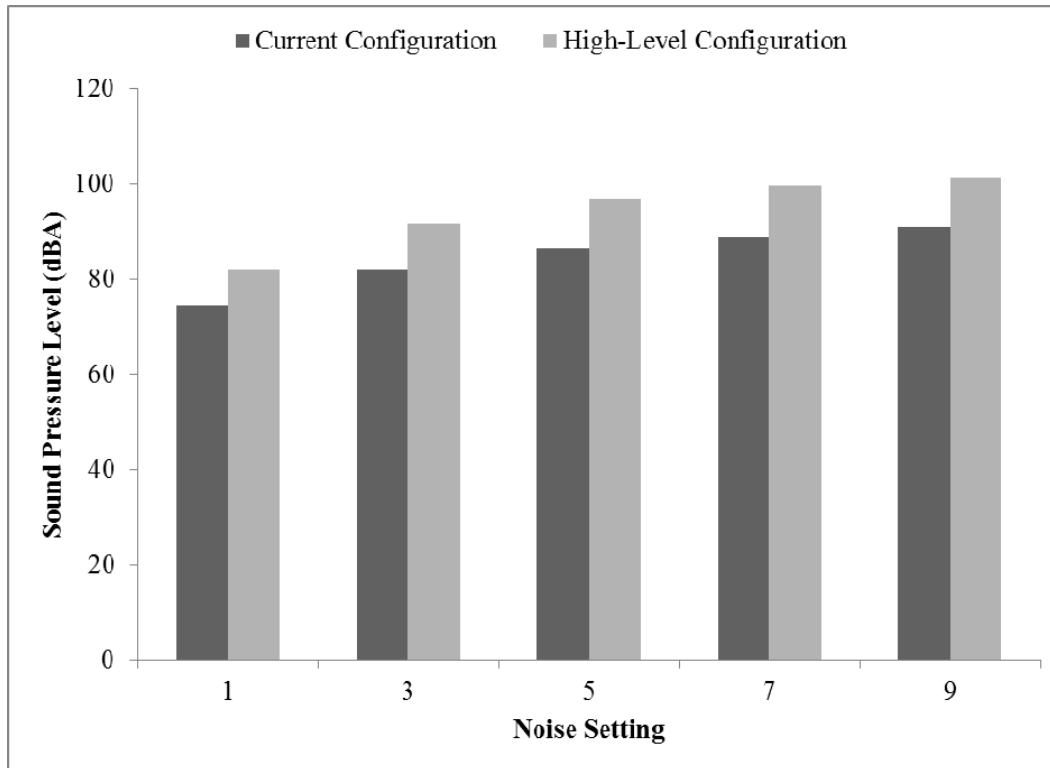


Figure 20. Observer A-weighted Overall Levels.

Controller

Figures 21 through 25 present the third octave band levels for the controller position at five of the noise settings for both the current base setup and with different speakers installed. Figure 26 presents the overall A-weighted levels recorded at the five noise settings for both setups.

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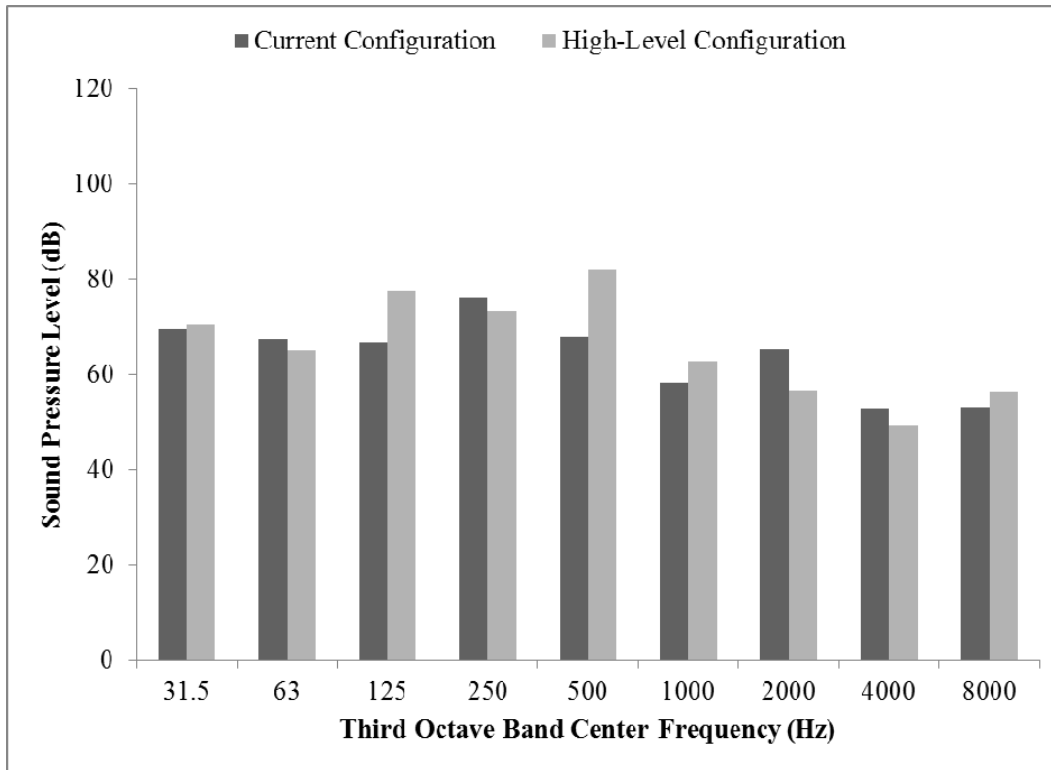


Figure 21. Controller Third Octave Band Levels (Noise Setting 1).

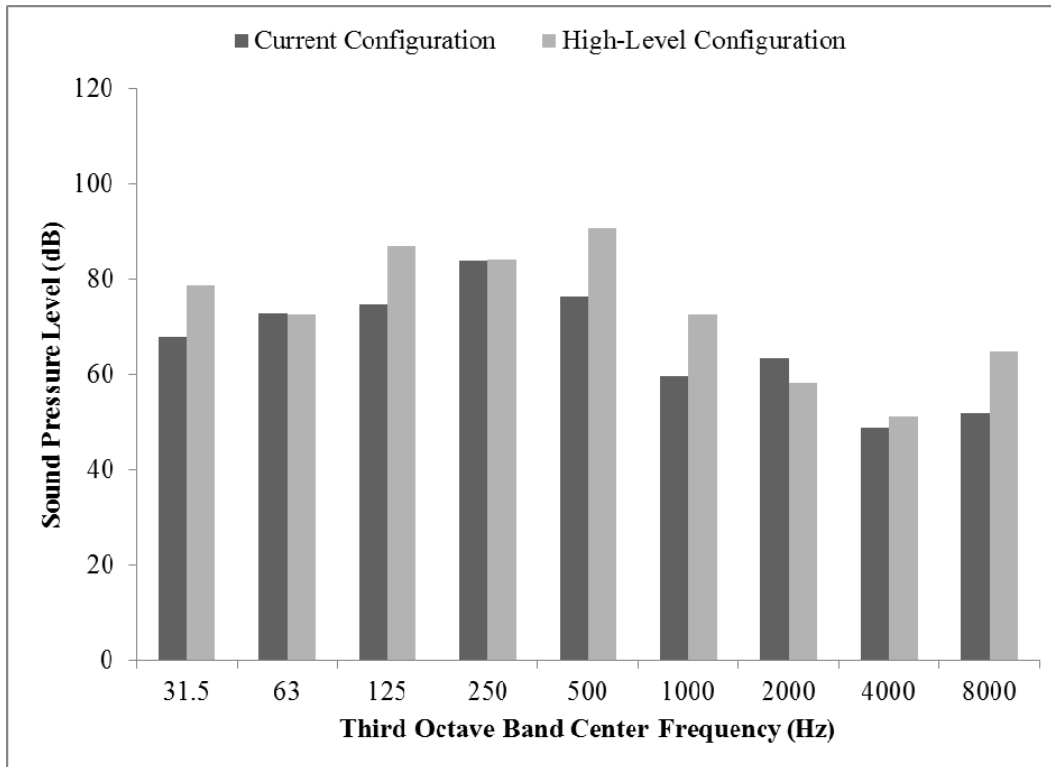


Figure 22. Controller Third Octave Band Levels (Noise Setting 3).

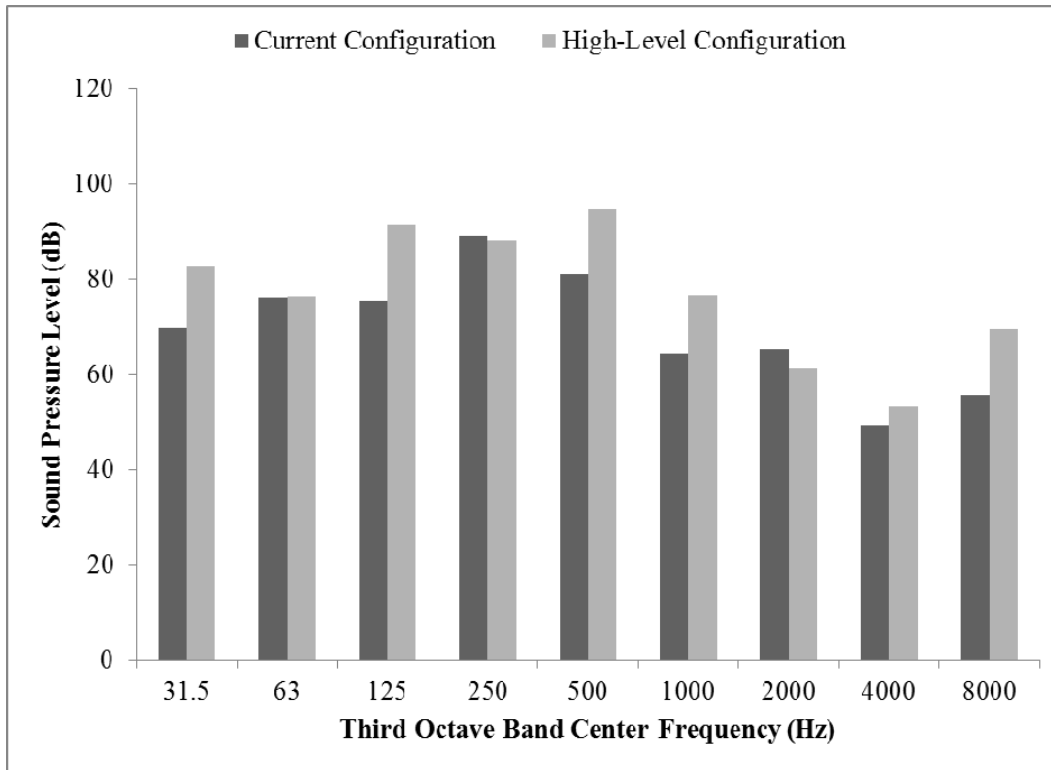


Figure 23. Controller Third Octave Band Levels (Noise Setting 5).

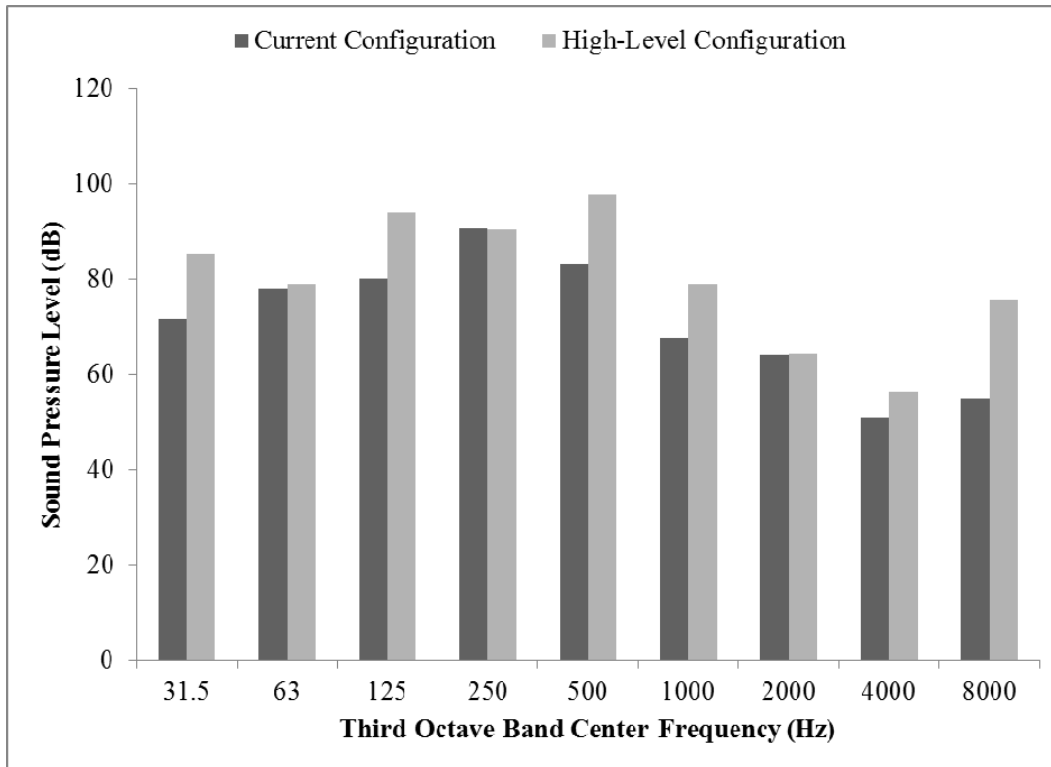


Figure 24. Controller Third Octave Band Levels (Noise Setting 7).

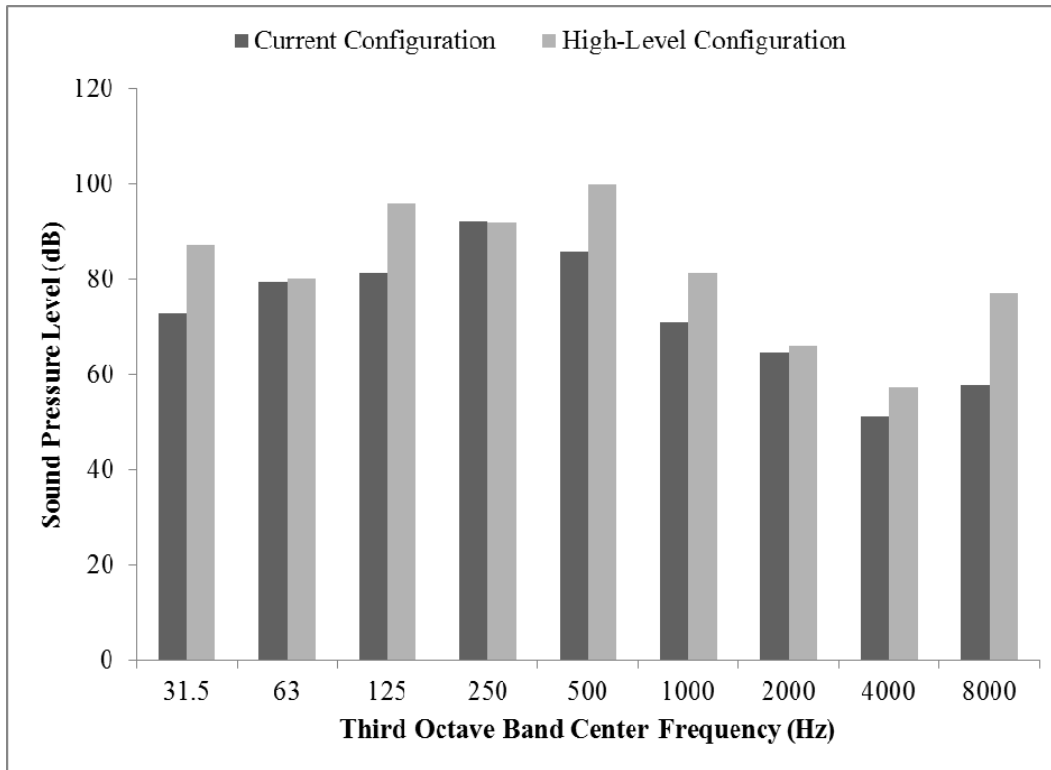


Figure 25. Controller Third Octave Band Levels (Noise Setting 9).

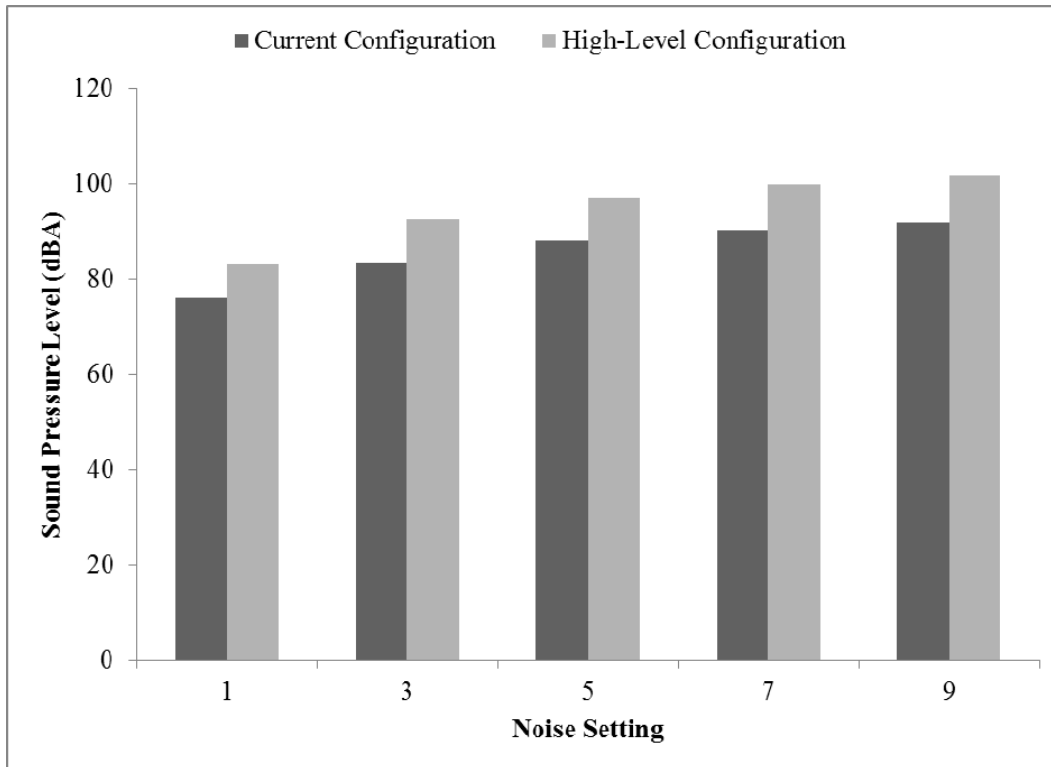


Figure 26. Controller A-weighted Overall Levels.

Discussion

The third octave band levels for the current base configuration for the NUH-60FS were predominantly lower at both pilot positions than those of the previous study done on the flight simulator. With different speakers installed, the levels at the 31.5, 125, 500, and 8000 Hz frequencies rose above those of the previous study. The overall A-weighted level was lower with the base configuration, but still exceeded 85 dBA at the same noise settings as the previous study. With the different speakers installed, the overall A-weighted level exceeded 85 dBA when the noise setting is at least set to one.

At the rear positions, the third octave band levels of the base speaker set are generally below those of the higher-level speakers. This difference is most consistent at the 31.5, 500, 1000, and 8000 Hz frequencies. The base configuration does not exceed 85 dBA until the noise setting is set to four, while the higher-level speakers exceed 85 dBA when the noise setting is set above one. Appendix A summarizes the third octave band levels and overall A-weighted levels for each of the noise settings at every position in the NUH-60FS.

Conclusions

The base configuration of the NUH-60FS show almost uniformly lower levels in comparison to the previous study conducted on the flight simulator. Higher noise levels are achievable with different speakers, but at the expense of altering the third octave band frequency levels. Even with these lower levels, people conducting research in USAARL's NUH-60FS flight simulator should wear hearing protection while the simulator is in operation.

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- Acoustical Society of America (ASA). (2016). ANSI S12.6-2016 American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors. Melville, NY: ASA.
- Gordon, E., & Ahroon, A. (2000). Noise Levels in the USAARL NUH-60 (Black Hawk) Aeromed Flight Simulator (Report No. 2000-19). Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory.
- United States Department of Defense. (2015). MIL-STD-1474E Department of Defense Design Criteria Standard: Noise Limits.

Appendix A. Third Octave Band Levels

Table A1. Base Third Octave Band Levels (Left Pilot)

Setting	Third Octave Band Level (dB)									Overall (dBA)
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
0	66.89	67.72	66.09	63.19	62.86	62.07	69.84	58.76	54.79	74.78
1	66.95	75.62	74.42	76.77	70.16	63.79	69.70	59.25	57.39	79.33
2	67.28	80.46	79.81	82.10	75.29	64.56	69.70	58.82	56.98	83.69
3	66.77	83.15	83.13	85.61	78.66	66.32	69.77	58.81	58.94	86.81
4	67.41	85.17	85.23	87.85	80.95	67.95	69.75	58.84	60.63	89.08
5	68.07	86.64	86.82	89.72	82.94	69.49	69.81	58.92	62.76	90.83
6	68.74	87.97	88.20	91.08	84.34	71.11	69.95	59.05	64.13	92.28
7	69.50	88.88	89.29	92.33	85.60	72.52	70.15	59.16	65.64	93.50
8	69.99	89.54	90.13	93.27	86.54	74.03	70.31	59.42	67.18	94.51
9	70.70	90.11	90.88	93.97	87.36	75.41	70.60	59.67	68.20	95.33

Table A2. Base Third Octave Band Levels (Right Pilot)

Setting	Third Octave Band Level (dB)									Overall (dBA)
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
0	65.15	65.49	64.51	60.84	64.02	59.64	69.78	57.84	51.88	73.93
1	65.22	72.48	73.04	79.44	73.13	62.19	69.78	58.21	55.72	80.34
2	65.55	76.62	78.55	84.81	78.43	62.89	69.74	57.91	57.67	85.21
3	65.01	79.28	81.90	88.16	82.06	64.96	69.82	57.99	60.30	88.48
4	65.77	81.32	84.03	90.41	84.40	66.61	69.97	58.10	62.35	90.73
5	66.43	82.67	85.57	92.09	86.20	68.50	69.74	58.30	63.78	92.47
6	67.11	84.02	86.98	93.56	87.73	70.00	69.81	58.47	65.28	93.88
7	67.85	84.89	88.11	94.75	88.92	72.03	70.08	58.72	65.63	95.07
8	68.42	85.55	88.91	95.70	89.88	73.83	70.38	59.04	66.42	96.03
9	69.16	86.15	89.67	96.44	90.78	75.55	70.52	59.49	67.26	96.80

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Table A3. Base Third Octave Band Levels (Observer)

Setting	Third Octave Band Level (dB)									Overall (dBA)
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
0	66.98	72.62	68.22	58.26	61.60	54.45	60.72	47.69	46.49	67.32
1	69.84	74.86	73.05	76.31	69.46	57.52	61.01	49.69	50.10	74.41
2	67.76	77.49	76.23	82.17	73.61	57.10	62.01	47.92	50.25	79.09
3	67.72	80.14	79.66	85.20	77.64	59.18	60.12	47.74	53.17	82.28
4	68.78	81.83	82.47	87.23	80.57	60.55	60.37	48.03	54.28	84.60
5	69.66	82.97	83.89	89.01	83.23	63.37	60.84	47.69	55.84	86.53
6	70.44	84.50	85.14	90.07	83.98	64.14	61.31	48.63	56.12	87.87
7	71.40	85.19	86.70	91.61	84.87	65.83	59.91	49.20	56.82	89.05
8	71.98	85.87	87.33	92.56	86.00	68.07	60.33	49.96	58.38	90.18
9	72.59	86.38	87.92	93.22	87.39	70.09	61.45	50.47	59.74	91.10

Table A4. Base Third Octave Band Levels (Controller)

Setting	Third Octave Band Level (dB)									Overall (dBA)
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
0	66.67	61.43	61.21	58.21	58.62	55.95	63.70	48.86	45.98	68.31
1	69.79	67.38	66.80	76.32	67.79	58.37	65.45	52.87	53.09	76.16
2	67.63	70.47	71.38	81.40	72.04	58.27	65.03	49.30	50.05	80.63
3	67.81	72.98	74.72	83.84	76.27	59.71	63.24	48.85	52.02	83.30
4	68.98	74.69	75.79	86.58	79.17	61.74	64.36	49.30	53.06	85.91
5	69.90	76.24	75.33	89.14	81.06	64.38	65.43	49.49	55.83	88.08
6	70.78	77.68	78.27	89.37	82.68	64.94	63.51	49.68	54.68	88.69
7	71.71	78.17	80.06	90.61	83.04	67.54	64.17	50.94	54.98	90.04
8	72.38	78.80	80.62	91.50	84.58	69.31	64.01	50.74	55.94	91.05
9	72.94	79.45	81.30	92.26	85.73	70.97	64.58	51.19	57.90	91.86

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Table A5. New Third Octave Band Levels (Left Pilot)

Setting	Third Octave Band Level (dB)									Overall (dBA)
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
0	68.61	62.94	64.00	58.69	63.22	60.62	67.73	58.09	54.72	73.77
1	69.70	75.18	90.44	78.14	83.13	70.08	67.89	58.53	66.82	86.83
2	73.62	80.69	96.48	84.13	89.22	75.12	68.57	59.72	71.67	92.80
3	75.61	83.99	99.85	87.43	92.73	77.99	69.59	60.68	78.91	96.64
4	77.91	86.61	103.04	90.69	94.61	81.10	70.12	61.31	77.24	98.57
5	79.46	88.66	104.75	92.92	97.27	81.72	71.84	62.14	76.00	100.45
6	80.96	89.93	106.27	94.25	98.76	82.76	73.44	62.81	78.50	101.82
7	81.71	90.76	107.73	95.55	100.85	83.05	73.69	64.07	82.79	103.31
8	82.74	91.44	108.83	96.26	101.56	84.99	74.84	65.35	83.95	104.21
9	83.82	92.65	109.55	97.02	102.32	87.01	75.54	66.29	86.27	105.26

Table A6. New Third Octave Band Levels (Right Pilot)

Setting	Third Octave Band Level (dB)									Overall (dBA)
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
0	67.32	64.26	62.48	58.68	64.09	59.85	66.07	57.81	53.70	72.33
1	69.04	77.19	88.30	77.40	82.86	69.68	66.50	58.19	63.65	88.32
2	72.89	82.66	94.32	83.18	89.19	74.61	67.78	59.46	67.91	94.48
3	75.14	85.91	97.70	86.59	92.83	77.72	69.34	60.53	73.49	98.30
4	77.44	87.86	100.05	88.70	95.65	80.83	69.74	60.48	72.36	100.18
5	78.97	87.88	101.85	90.58	97.77	83.51	71.00	61.30	75.73	102.23
6	80.51	89.28	103.41	92.07	99.10	85.63	72.27	61.87	73.14	103.64
7	81.28	91.68	104.67	93.29	100.48	84.81	73.37	62.93	75.46	104.80
8	82.31	93.09	105.61	93.96	101.60	86.92	73.81	64.14	73.34	105.77
9	83.35	92.08	106.51	94.78	102.49	87.43	74.70	64.93	77.41	106.63

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Table A7. New Third Octave Band Levels (Observer)

Setting	Third Octave Band Level (dB)									Overall (dBA)
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
0	69.98	69.24	65.19	54.88	56.65	51.51	52.30	45.45	47.23	62.97
1	71.86	70.11	73.27	69.87	80.35	61.85	53.82	45.77	54.94	81.93
2	76.12	72.21	78.41	76.79	86.72	67.15	54.31	48.50	58.63	87.84
3	78.46	73.92	82.26	80.28	89.85	70.84	56.07	48.14	63.54	91.73
4	80.51	76.26	85.89	81.51	93.11	76.25	58.16	50.09	68.36	95.46
5	82.13	78.26	87.11	84.61	95.71	78.44	59.26	50.89	68.51	97.04
6	83.65	78.73	89.30	84.03	97.22	81.45	61.27	53.18	72.45	98.46
7	84.38	78.66	90.29	87.01	98.64	80.21	62.23	53.95	71.00	99.63
8	85.37	78.46	91.12	88.21	99.61	82.04	63.43	54.55	71.07	100.66
9	86.45	80.77	91.97	88.02	99.50	81.49	64.75	55.48	72.81	101.32

Table A8. New Third Octave Band Levels (Controller)

Setting	Third Octave Band Level (dB)									Overall (dBA)
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	
0	64.90	59.23	57.19	55.72	55.34	54.67	56.26	49.22	47.83	64.47
1	70.70	65.06	77.55	73.39	82.00	62.89	56.83	49.40	56.58	83.20
2	75.84	69.74	83.75	79.63	86.98	68.93	57.20	49.95	61.20	89.22
3	78.84	72.67	87.02	83.98	90.85	72.55	58.21	51.22	64.88	92.61
4	81.14	74.71	89.27	85.12	93.46	74.14	60.48	52.81	67.93	94.87
5	82.81	76.57	91.46	88.05	94.78	76.63	61.35	53.28	69.60	96.93
6	84.36	77.75	92.89	88.17	96.77	78.43	63.28	54.57	73.46	98.75
7	85.45	78.91	94.11	90.28	97.83	79.03	64.36	56.28	75.67	99.95
8	86.50	79.75	95.08	91.53	99.47	80.34	63.70	56.92	77.97	101.26
9	87.17	80.20	96.16	91.98	100.01	81.30	66.10	57.52	77.23	101.66



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