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Impulse Noise Levels of the UH-60A/L Black Hawk Helicopter Cockpit Air Bag System

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Aircrew Protection Division

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A Cockpit Airbag System (CABS) is being developed for the UH-60A/L Black Hawk Helicopter. The U.S. Army Aeromedical Research Laboratory conducted tests to determine the risks to crewmembers and passengers associated with exposure to high impulse noise levels expected during an inadvertent system deployment. A series of 21 airbag deployment tests were conducted in a static UH-60A helicopter. Peak sound pressure levels ranged from 134 dB to 161 dB. Levels at pilot, copilot, and gunner stations exceeded 140 dB during all 21 deployments. Levels in the passenger compartment exceeded 140 dB during 9 of the 21 deployments. Army policy requires the aircrew in the UH-60 helicopter to wear helmets that provide hearing protection or a combination of helmet and earplugs. Passengers are required to wear protective earplugs or muffs or a combination of muffs and earplugs. This level of hearing protection also meets the requirements for protection against high impulse noise levels created by the deployment of airbags. Therefore, if the required hearing protective devices are worn, the potential of inadvertent deployment of the CABS in the UH-60 helicopter poses no additional risk to the hearing of crew and passengers.

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Introduction

The UH-60A/L Black Hawk Helicopter Cockpit Airbag System (CABS) development program is managed by the U.S. Army Aviation Applied Technology Directorate (AATD) with oversight from the Office of the Program Manager, Aircrew Integrated Systems (PM-ACIS). Imminent fielding of the CABS is anticipated. In order for this program to obtain an airworthiness release (AWR), the risk of injury to crewmembers during an inadvertent or unnecessary system deployment must be defined. The PM-ACIS requested that the U.S. Army Aeromedical Research Laboratory (USAARL) Aircrew Protection Division determine the risk and severity of head, neck, chest, and upper extremity injuries that could be expected in a system deployment (McEntire et al., 1999).

USAARL's Acoustics Team conducted adjunct tests to determine the risks to hearing associated with exposure to high impulse noise levels caused by the deployment of airbags. The objectives of the noise measurements were to determine the noise exposure levels and expected risks of noise-induced hearing loss to crew and passengers during deployment, whether deployed individually or in combinations of two or all four airbags. A series of 21 CABS deployment tests were conducted. This report documents the potential risks to hearing associated with exposure to high impulse noise levels that could be expected in a system deployment.

Impulse noise levels produced by the deployment of the CABS have not previously been documented. In the 1960's and early 1970's, research on the impulse noise associated with automobile airbag deployment was conducted to determine criteria for risk of noise-induced hearing loss and several criteria were proposed (Nixon, 1969 and Allen et al., 1971). More recent automobile airbag deployment studies performed in the 1990's have shown impulse noise levels that ranged from 150 to 170 decibels (dB) peak sound pressure level (SPL) (Rouhana et al., 1994; Rouhana, Vaundle, and Webb, 1998; and Price and Kalb 1999). Anecdotal accounts of noise-induced hearing loss that may be attributed to the deployment of airbags in low speed car crashes have been reported (Saunders, Slattery, and Luxford, 1998; and Buckley, Setchfield, and Frampton, 1999).

Impulse noise produced by military weapons is known to be hazardous to hearing and damage risk criteria for noise-induced hearing loss has been developed (Coles et al., 1968; Ward, 1968; and Patterson et al., 1985). The Department of Defense (DoD) (1997) established criteria for noise limits in the design of military systems and equipment that emit acoustic noise, Military Standard (MIL-STD) 1474D, "Noise Limits." The criteria contained in MIL-STD-1474D is more stringent than the Occupational Safety and Health Administration (OSHA) standards and is required to be used in lieu of OSHA standard (29 CFR 1910.95, 1996).

Through extensive research by USAARL and other laboratories, impulse noise produced by modern military weapon systems has been well documented as a significant hazard to hearing (Patterson et al., 1986 and Patterson and Johnson 1994). Certain physical characteristics of impulse noise sources have been identified as factors important in causing hearing damage. These factors include maximum peak amplitude and duration (Figure 1). The short duration of impulse noise (microseconds to several hundred milliseconds) can be intense enough to cause hearing damage.

MIL-STD-1474D Requirement 4, "Impulse Noise In Personnel-Occupied Areas," establishes impulse noise limits and B-duration values (Figure 2) and prescribes testing requirements and measurement techniques for determining conformance to impulse noise limits. The B-duration is used to establish the maximum allowable peak pressure level. B-duration is the total time that the positive and negative pressure fluctuations exceed a level 20 dB down from the peak. The A-duration, the time interval from where the pressure wave first rises above the baseline ambient pressure to its principal positive peak to the time it first returns to zero, is used to calculate B-duration. Applicable impulse noise limits are identified by the expected number of daily exposures and the type of hearing protection required.

Methods and instrumentation

A static UH-60A Black Hawk helicopter was used for the series of 21 CABS deployment tests. These tests consisted of 20 single airbag deployments (5 left frontal, 5 right frontal, 5 right lateral, and 5 left lateral airbags) and 1 full ship-set deployment (2 frontal and 2 lateral airbag modules).

A male Hybrid III manikin was used in the frontal bag tests and a female Hybrid III manikin, on-loan from the U.S. Air Force, was used for the lateral airbag tests. Both manikins were used in the full system deployment test. In each test, a manikin was seated in either the pilot or copilot seat, in a neutral position, near the aircraft's design eye point. Generally, body positioning of manikins was such that the left hand was grasping the collective and the right hand was grasping the cyclic. The feet were positioned so that the toes touched the pedals. Each manikin was dressed in a flight suit, boots, and flight helmet. In some frontal tests, night vision goggles (NVGs), modified with load cells replacing the objective lens, were mounted on the flight helmet of the male manikin. Impulse noise levels were recorded at 8 locations within the aircraft as described in Table 1. Positions of the manikins, seats, and special conditions for each test are described in Table 2. Layout of the UH-60A crew and passenger locations and transducer locations are shown in Figure 3. Figure 4 shows the CABS in the UH-60A, with the male manikin in the pilot seat. The aircraft's door and window adjacent to where the manikin was seated were closed during all tests. All other aircraft doors and windows were open during deployment of the airbags.

Eight locations, flight crew, mission crew, and passenger stations were instrumented with PCB Piezotronics, Inc. pressure transducers, Model ST-2, oriented at grazing incidence (90 degrees) with reference to the location of the airbag being deployed (Figure 5). The transducers were powered and conditioned by a PCB Piezotronics, Inc. 12-channel power conditioner, Model 483. Transducer outputs were amplified and low-passed filtered at 40 kHz by a Stewart Electronics multi-channel filter/amplifier system, Model KEMO VBF/40 (response: -80dB at 1.5f). Pressure-time signatures were digitized by Pacific Instruments transient data recorders (TDRs), Model 9820, set to a sampling rate of 125,000 samples per second. MIL-STD-1474D specifies a minimum sampling rate of 160,000 samples per second. The rate was set at 125,000 samples per second, consistent with past measurement practices (Patterson et al., 1997). The

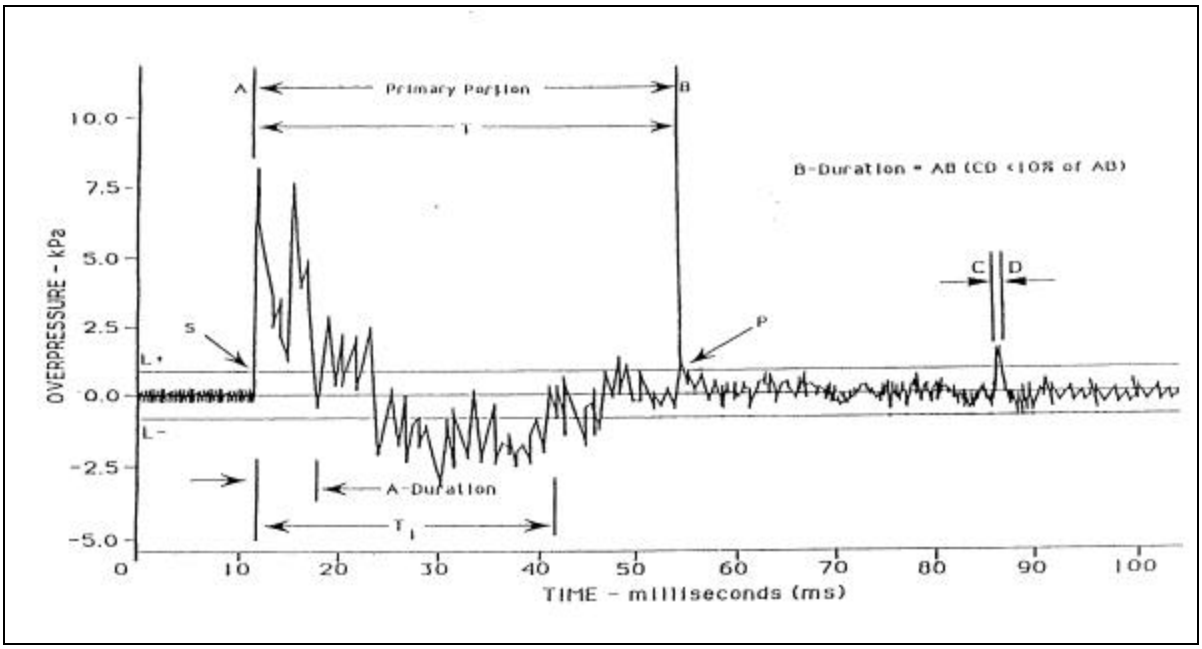

Figure 1. A sample determination of B-duration, from MIL-STD-1474D.

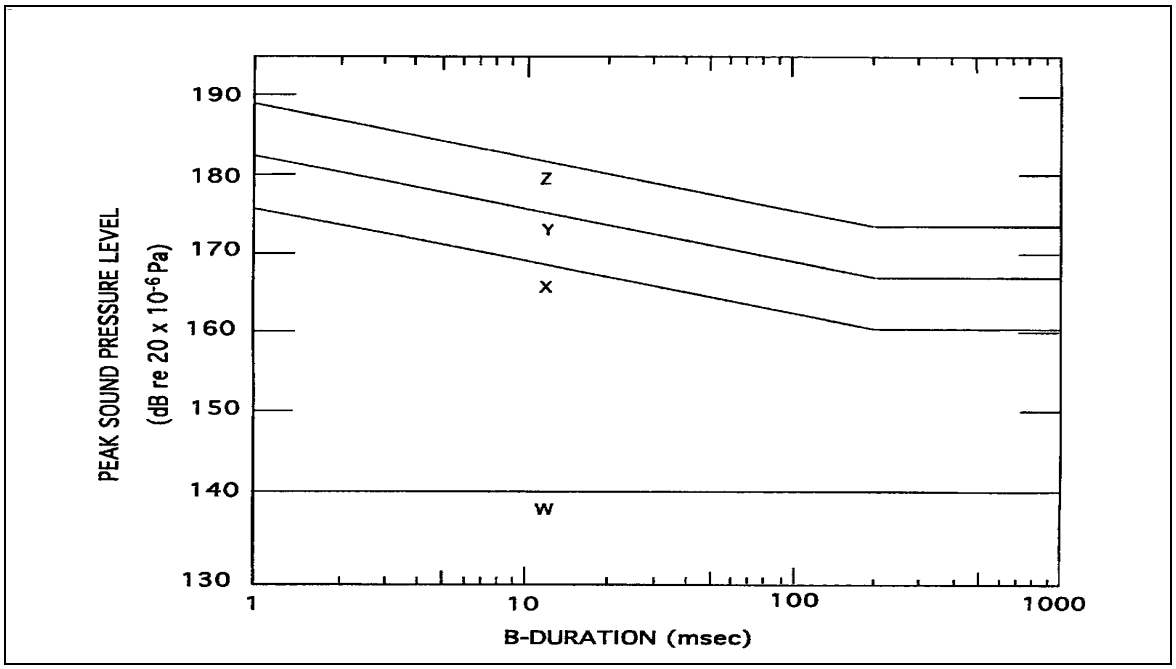

Figure 2. Peak sound pressure levels and B-duration limits for impulse noise, from MIL-STD-1474D.

resulting digital records were transferred to a personal computer (PC) and stored in files on disk. Each digital record consisted of 2^{15} data points.

The data acquisition system was calibrated with an acoustic reference signal, produced by a Brüel & Kjær (B&K) pistonphone, Type 4220; to provide sound pressure levels referenced to 20 micropascals, through a B&K ½ inch microphone, Type 4165. The microphone was powered and conditioned by a B&K preamplifier, Type 2619. Pressure transducers were calibrated using an acoustic signal produced by a B&K high intensity calibrator, Type 4221, referenced to 20 micropascals. The reference signals were analyzed and stored in data files on the control computer. The system was housed in a mobile research van for portability to the test site.

Table 1.
Transducer locations in the UH-60A helicopter for the CABS deployment tests.

Location	Crew and passenger stations
0	Copilot – left ear
1	Copilot – right ear
2	Pilot - left ear
3	Pilot - right ear
4	Left gunner - right ear
5	Right gunner - left ear
6	Passenger compartment, left side
7	Passenger compartment, right side

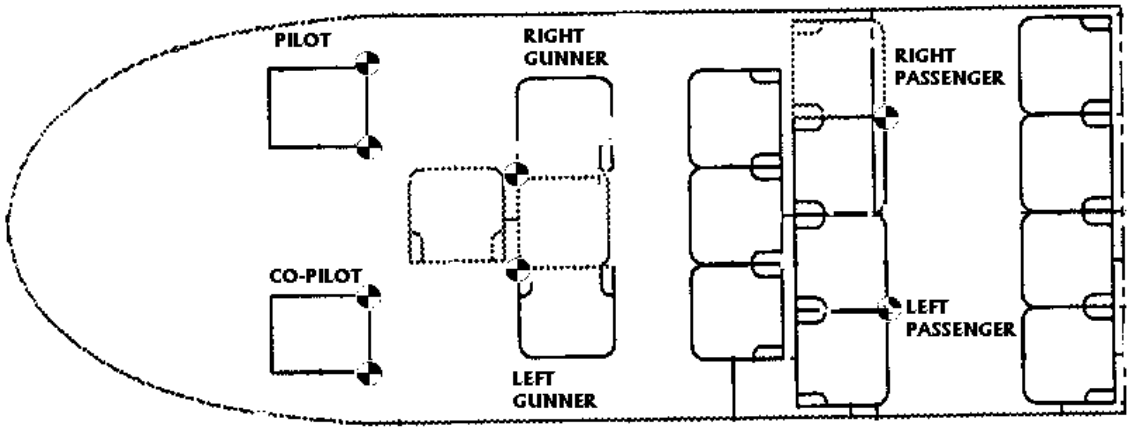

Figure 3. Layout of the UH-60A helicopter. Circles indicate the locations of the pressure transducers during impulse noise measurements.

Table 2.
Manikin positioning for CABS deployment tests.

Test name	Seat fore/aft	Seat vertical	Body position	Special condition
LLAT01	Full aft	Down	Toward bag	Collective ht = 16.5”
LLAT02	Midpoint	Midpoint	Toward bag	Collective ht = 19.7”
LLAT03	Full fore	Midpoint	Toward bag	Collective ht = 17.7’
LLAT04	Full aft	Midpoint	Toward bag	Collective ht = 21.2”
LLAT05	Midpoint	Midpoint	Toward bag	Collective ht = 19.7”
RLAT01	Full aft	Midpoint	Toward bag	Cyclic right
RLAT02	Full aft	Above midpoint	Toward bag	Cyclic right aft
RLAT03	Full aft	Above midpoint	Toward bag	Cyclic right forward
RLAT0	Midpoint	Midpoint	Toward bag	Cyclic right
RLAT05	Full fore	Above midpoint	Toward bag	Cyclic right aft
LFRT01	Aft	Midpoint	Leaning forward	Without NVG, head on glare shield
LFRT02	Aft	Midpoint	Leaning forward	With NVG, head on glare shield
LFRT03	Aft	Full up	Leaning forward	With NVG, looking over a/c nose
LFRT04	Aft	Full down	Leaning forward & inboard	With NVG, leaning forward & inboard, reaching for tail rotor servo control switch
LFRT05	Midpoint	Full down	Leaning forward	With NVG, leaning forward but more upright, looking at instrument panel
RFRT01	Mid	Full up	Leaning forward	With NVG, leaning forward, helmet near glare shield edge
RFRT02	Mid	Full up	Leaning forward	Without NVG, leaning forward, helmet hear glare shield edge
RFRT03	Mid	Full up	Leaning forward & Inboard	Without NVG, leaning forward & inboard, reaching for tail rotor servo control switch
RFRT04	Mid	Full up	Leaning forward & outboard	Without NVG, leaning forward & outboard, (to simulate “clearing left”)
RFRT05	Full fore	Mid	Midpoint	Without NVG, leaning forward & upright, looking at instrument panel
LFULL	Aft	Up	Centered	Leaning forward & outboard, shoulders rotated outboard, helmet near A-pillar (to simulate “clearing left”)
RFULL				
	Full fore	Midpoint	Centered	Leaning forward slightly & left arm reaching over cyclic to adjust altimeter

LLAT - Left lateral airbag
RLAT - Right lateral airbag
LFRT - Left front airbag
RFRT - Right front airbag
LFULL - Left full (front & lateral) airbags
RFULL - Right full (front & lateral) airbags

Figure 4. The UH-60A/L helicopter Cockpit Airbag System. The USAARL instrumented MIDAS anthropometric manikin is positioned in the pilot's seat (arrows point to three pressure transducers).

Figure 5. Typical pressure transducers used in the CABS deployment tests, oriented at grazing incidence, positioned at the pilot's left ear and right ear locations (see arrows).

Results and discussion

Results of the 21 deployment tests showed measured peak impulse sound pressure levels ranging from 134.0 dB to 161.3 dB and B-durations ranging from 39.5 milliseconds (ms) to 92.8 ms. During all 21 deployments, peak levels at pilot, copilot, left gunner and right gunner locations exceeded 140 dB. Peak levels at the left passenger compartment location, ranging from 134.0 dB to 147.2 dB, exceeded the 140 dB limit during three of the five left frontal deployments and the full ship-set deployments. Peak levels at the right passenger compartment location, ranging from 134.8 dB to 147.6 dB, exceeded 140 dB during two of the five left frontal deployments, four of the five right frontal deployments, and the full ship-set deployments. Highest peak levels for all locations occurred during deployment of the full ship-set airbags, ranging from 147.2 dB, at the left passenger compartment, to 161.3 dB at the pilot location.

Table 3 shows mean peak SPL for the left lateral, right lateral, left frontal, and right frontal deployments. Table 4 shows the measured peak SPL of the full ship-set deployment. Some data were lost during some airbag deployments because of equipment malfunctions.

The characteristics of the impulse noise, peak levels and durations for each airbag deployment test, are shown in the tables in Appendix A. Graphs of pressure-time histories of each airbag deployment test are shown in Appendix B.

The peak level of the impulse noise was dependent on airbag and sensor locations. During all test scenarios, the pilot, copilot, left gunner, and right gunner stations, impulse noise levels exceed the 140 dB peak exposure limit established by the Department of Defense Hearing Conservation Program criteria (DODI 6055.12, 1991). The left passenger compartment levels exceeded the limit during left frontal and full ship-set deployments. The right passenger levels compartment exceeded the limit during two left frontal deployments, four right frontal deployments, and the full ship-set deployment.

Table 3.

Mean peak sound pressure levels in dB for deployment of left lateral, right lateral, left frontal, and right frontal cockpit airbags (five deployments per test) at locations shown.

	Mean Peak SPL (dB)			
Location	Left lateral	Right lateral	Left frontal	Right frontal
Copilot left ear	155.1	147.5	156.3	149.8
Copilot right ear	150.6	147.1	153.6	150.6
Pilot left ear	146.6	151.5	151.4	153.7
Pilot right ear	146.8	154.3	151.2	154.8
Left gunner right ear	142.3	144.1	147.7	148.3
Right gunner left ear	144.7	142.1	147.3	147.4
Passenger compartment - left	135.3	136.3	140.1	139.2
Passenger compartment - right	136.4	137.4	139.0	140.7

Table 4.
Peak sound pressure levels in dB during simultaneous deployment of full left and full right (lateral and frontal) cockpit airbags at the locations shown.

Location	Peak SPL (dB)
Copilot left ear	157.3
Copilot right ear	158.6
Pilot left ear	160.6
Pilot right ear	161.3
Left gunner right ear	154.8
Right gunner left ear	156.6
Passenger compartment – left	147.2
Passenger compartment – right	147.6

Conclusion

Personnel exposed to impulse noise levels above 140 dB peak are required to use hearing protectors for any number of exposures per day as defined in the Department of Army Hearing Conservation criteria (DA PAM 40-501, 1991). Current Army policy requires aircrew in the UH-60 helicopter to wear protective helmets that provide hearing protection, and passengers to wear hearing protector earplugs or muffs. A recent change to the UH-60A/L and EH-60A helicopter technical manual (TM 1-1520-237-10, 1996, Change 4, 1999) requires that both helmet and ear plugs shall be worn by all crew members when window guns are firing, when flights exceed 100 minutes during any 24-hour period, or when speeds are above 120 knots. This level of hearing protection also meets the requirements for protection against the high impulse noise levels created by the deployment of a single airbag or the simultaneous deployment of any combination of airbags. Therefore, if the required hearing protective devices are worn, the potential of inadvertent deployment of airbags in the UH-60 helicopter poses no additional risk to the hearing of crew and passengers.

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Appendix A.

CABS deployment tests peak levels and durations.
Tables A-1 through A-5

Notes:
1. Dash (-) indicates data record was not captured during deployment
2. Asterisk (*) indicates value derived from analysis of pressure-time graph
3. SPL (dB) Sound pressure level in decibels
4. P-Peak (kPa) Positive peak level in kilopascals
5. N-Peak (kPa) Negative peak level in kilopascals

Table A-1.

Peak levels and durations during deployment of left lateral cockpit airbags at locations shown.

Test	Location	SPL (dB)	P-Peak (kPa)	N-Peak (kPa)	A-duration (ms)	B-duration (ms)
LLAT01						
	Copilot left ear	152.6		0.85	-1.19	2.47
50.31						
	Copilot right ear	149.2	0.58	-0.81	3.41	64.78
	Pilot left ear	147.9	0.50	-0.64	1.90	63.12
	Pilot right ear	148.6	0.54	-0.63	2.34	47.40
	Left gunner right ear	140.8	0.22	-0.54	0.53	58.66
	Right gunner left ear	143.5	0.30	-0.41	3.52	86.29
	Passenger compartment - left	136.2	0.13	-0.23	3.52	61.06
	Passenger compartment - right	136.2	0.13	-0.19	3.52	61.06
LLAT02						
	Copilot left ear	156.9	1.40	-1.42	0.72	38.84
	Copilot right ear	149.5	0.60 *			
	Pilot left ear	146.0	0.40	-0.43	4.10	51.25
	Pilot right ear	146.2	0.41	-0.49	3.07	50.63
	Left gunner right ear	142.6	0.27	-0.34	4.02	87.98
	Right gunner left ear	144.3	0.33	-0.36	0.78	53.26
	Passenger compartment - left	135.6	0.12	-0.15	1.94	78.56
	Passenger compartment - right	136.2	0.13	-0.16	3.09	77.46
LLAT03						
	Copilot left ear	156.0	1.27	-1.65	1.95	51.61
	Copilot right ear	152.1	0.81	-0.91	0.62	47.70
	Pilot left ear	146.2	0.41	-0.66	1.04	56.90
	Pilot right ear	147.2	0.46	-0.49	1.71	34.14
	Left gunner right ear	145.1	0.36	-0.41	0.86	64.09
	Right gunner left ear	148.3	0.52	-0.45	0.69	53.18
	Passenger compartment - left	136.3	0.13	-0.16	0.78	75.27
	Passenger compartment - right	137.5	0.15	-0.21	0.75	77.32
LLAT04						
	Copilot left ear	151.9	0.79	-1.13	0.39	36.97
	Copilot right ear	150.6	0.68	-0.85	2.09	64.58
	Pilot left ear	147.0	0.45	-0.59	1.92	61.43
	Pilot right ear	146.4	0.42	-0.48	2.48	57.44
	Left gunner right ear	141.6	0.24	-0.37	1.63	109.86
	Right gunner left ear	142.9	0.28	-0.48	3.27	74.07
	Passenger compartment - left	134.0	0.10	-0.19	3.27	74.07
	Passenger compartment - right	136.9	0.14	-0.20	3.27	74.07
LLAT05						
	Copilot left ear	156.9	1.40	-1.69	0.60	45.03
	Copilot right ear	150.9	0.70 *			
	Pilot left ear	145.6	0.38	-0.38	2.78	62.65
	Pilot right ear	145.3	0.37	-0.37	2.16	62.65
	Left gunner right ear	140.8	0.22	-0.28	1.99	100.98
	Right gunner left ear	143.2	0.29	-0.25	1.29	58.69
	Passenger compartment - left	134.0	0.10	-0.16	1.28	92.93
	Passenger compartment - right	134.8	0.11	-0.16	4.64	92.93

Table A-2.

Peak levels and durations during deployment of right lateral cockpit airbags at locations shown.

Test	Location	SPL (dB)	P-Peak (kPa)	N-Peak (kPa)	A-duration (ms)	B-duration (ms)
RLAT01						
	Copilot left ear	148.9	0.56	-0.42	0.41	47.22
	Copilot right ear	146.0	0.40	-0.59	2.46	68.80
	Pilot left ear	149.7	0.61	-1.24	0.77	57.39
	Pilot right ear	154.9	1.11	-1.84	3.44	59.24
	Left gunner right ear	145.5	0.38	-0.52	0.86	40.30
	Right gunner left ear	140.4	0.21	-0.52	3.82	79.44
	Passenger compartment - left	-	-	-	-	-
	Passenger compartment - right	-	-	-	-	-
RLAT02						
	Copilot left ear	146.6	0.43	-0.49	0.76	53.26
	Copilot right ear	148.6	0.54	-0.53	2.37	60.52
	Pilot left ear	153.6	0.96	-0.91	3.08	67.74
	Pilot right ear	154.7	1.09	-1.96	0.64	60.60
	Left gunner right ear	144.1	0.32	-0.52	1.65	81.29
	Right gunner left ear	143.2	0.29	-0.44	2.32	75.46
	Passenger compartment - left	134.0	0.10	-0.26	2.05	109.63
	Passenger compartment - right	138.1	0.16	-0.19	2.05	54.06
RLAT03						
	Copilot left ear	146.2	0.41	-0.43	0.52	45.06
	Copilot right ear	146.4	0.42	-0.57	2.43	56.74
	Pilot left ear	149.4	0.59	-0.95	1.91	63.79
	Pilot right ear	153.2	0.92	-1.67	0.76	39.19
	Left gunner right ear	141.9	0.25	-0.60	3.11	78.94
	Right gunner left ear	142.2	0.26	-0.46	2.87	77.90
	Passenger compartment - left	138.1	0.16	-0.21	2.87	41.34
	Passenger compartment - right	135.6	0.12	-0.23	2.87	41.57
RLAT04						
	Copilot left ear	146.6	0.43	-0.41	1.11	39.14
	Copilot right ear	147.8	0.49	-0.54	1.55	58.21
	Pilot left ear	149.5	0.60 *			
	Pilot right ear	-	-	-	-	-
	Left gunner right ear	143.8	0.31	-0.53	1.20	80.90
	Right gunner left ear	141.6	0.24	-0.37	2.68	97.51
	Passenger compartment - left	135.6	0.12	-0.16	2.68	57.54
	Passenger compartment - right	136.2	0.13	-0.23	2.68	62.50
RLAT05						
	Copilot left ear	148.6	0.54	-0.62	1.61	33.06
	Copilot right ear	146.2	0.41	-0.64	1.63	57.36
	Pilot left ear	154.1	1.01	-1.00	1.94	52.13
	Pilot right ear	-	-	-	-	-
	Left gunner right ear	144.6	0.34	-0.51	1.50	77.67
	Right gunner left ear	142.9	0.28	-0.39	1.74	62.38
	Passenger compartment - left	136.9	0.14	-0.24	1.74	58.46
	Passenger compartment - right	139.1	0.18	-0.23	0.50	70.62

Table A-3.

Peak levels and durations during deployment of left frontal cockpit airbags at locations shown.

Test	Location	SPL (dB)	P-Peak (kPa)	N-Peak (kPa)	A-duration (ms)	B-duration (ms)
LFRT01						
	Copilot left ear	157.0	1.42	-1.53	2.11	41.29
	Copilot right ear	153.2	0.92	-0.93	2.13	43.65
	Pilot left ear	152.8	0.87	-0.64	1.66	41.67
	Pilot right ear	151.0	0.71	-0.48	1.50	36.98
	Left gunner right ear	-	-	-	-	-
	Right gunner left ear	148.0	0.51	-0.39	4.46	52.41
	Passenger compartment - left	-	-	-	-	-
	Passenger compartment - right	138.1	0.16	-0.22	8.05	95.92
LFRT02						
	Copilot left ear	156.8	1.38	-1.13	2.22	40.09
	Copilot right ear	153.0	0.89	-0.91	2.24	44.98
	Pilot left ear	152.0	0.80	-0.55	2.02	55.75
	Pilot right ear	151.2	0.73	-0.81	1.14	58.24
	Left gunner right ear	-	-	-	-	-
	Right gunner left ear	147.2	0.46	-0.49	1.58	57.76
	Passenger compartment - left	140.8	0.22	-0.18	2.06	63.25
	Passenger compartment - right	138.6	0.17	-0.23	2.06	83.90
LFRT03						
	Copilot left ear	156.2	1.29	-1.24	2.30	43.56
	Copilot right ear	155.5	1.19	-1.03	2.43	45.35
	Pilot left ear	152.0	0.81	-0.79	2.86	45.74
	Pilot right ear	153.2	0.91	-0.72	1.97	39.63
	Left gunner right ear	-	-	-	-	-
	Right gunner left ear	147.8	0.49	-0.51	1.21	47.23
	Passenger compartment - left	140.8	0.21	-0.21	5.30	77.66
	Passenger compartment - right	140.4	0.21	-0.29	6.27	85.20
LFRT04						
	Copilot left ear	157.6	1.51	-1.20	2.54	43.95
	Copilot right ear	153.3	0.92	-0.97	0.09	26.66
	Pilot left ear	148.9	0.56	-0.54	3.72	53.18
	Pilot right ear	148.0	0.50	-0.49	2.71	58.09
	Left gunner right ear	145.0	0.37	-0.51	3.53	100.30
	Right gunner left ear	145.6	0.38	-0.53	6.15	71.08
	Passenger compartment - left	140.4	0.21	-0.23	2.24	77.61
	Passenger compartment - right	137.5	0.15	-0.24	3.13	84.40
LFRT05						
	Copilot left ear	153.4	0.94	-1.33	1.83	51.10
	Copilot right ear	152.6	0.85	-0.76	1.66	74.46
	Pilot left ear	150.6	0.68	-0.70	1.71	43.18
	Pilot right ear	152.0	0.80	-0.56	0.96	42.08
	Left gunner right ear	149.5	0.60	-0.43	1.76	57.11
	Right gunner left ear	147.6	0.48	-0.48	0.55	50.12
	Passenger compartment - left	138.6	0.17	-0.17	6.38	71.55
	Passenger compartment - right	140.0	0.20	-0.31	2.19	75.42

Table A-4.

Peak levels and durations during deployment of right frontal cockpit airbags at locations shown.

Test	Location	SPL (dB)	P-Peak (kPa)	N-Peak (kPa)	A-duration (ms)	B-duration (ms)
RFRT01						
	Copilot left ear	150.0	0.63	-0.48	0.94	48.04
	Copilot right ear	151.7	0.77	-0.50	1.48	57.25
	Pilot left ear	153.6	0.96	-0.71	0.85	56.78
	Pilot right ear	153.8	0.99	-0.88	2.35	59.58
	Left gunner right ear	147.6	0.48	-0.47	2.90	59.87
	Right gunner left ear	146.6	0.42	-0.47	2.76	68.77
	Passenger compartment - left	138.6	0.17	-0.27	1.03	78.35
	Passenger compartment - right	138.1	0.16	-0.23	0.87	71.13
RFRT02						
	Copilot left ear	149.9	0.63	-0.58	1.37	39.16
	Copilot right ear	149.7	0.61	-0.67	1.48	55.88
	Pilot left ear	152.8	0.87	-0.85	1.51	62.77
	Pilot right ear	154.0	1.00	-1.01	2.41	62.08
	Left gunner right ear	146.6	0.43	-0.48	2.08	53.66
	Right gunner left ear	147.4	0.47	-0.60	2.10	74.51
	Passenger compartment - left	139.5	0.19	-0.22	5.85	73.94
	Passenger compartment - right	140.8	0.22	-0.18	2.26	58.26
RFRT03						
	Copilot left ear	149.1	0.57	-0.54	1.14	42.32
	Copilot right ear	149.8	0.62	-0.64	0.68	40.38
	Pilot left ear	154.7	1.09	-1.53	2.05	47.22
	Pilot right ear	156.5	1.34	-1.25	1.87	39.87
	Left gunner right ear	150.0	0.63	-0.54	4.19	57.39
	Right gunner left ear	147.6	0.48	-0.41	2.73	56.56
	Passenger compartment - left	139.1	0.18	-0.26	6.23	88.71
	Passenger compartment - right	141.6	0.24	-0.22	2.44	63.68
RFRT04						
	Copilot left ear	150.1	0.64	-0.58	2.02	38.64
	Copilot right ear	150.2	0.65	-0.60	1.62	39.37
	Pilot left ear	152.9	0.88	-1.10	1.98	38.86
	Pilot right ear	154.9	1.11	-1.32	2.08	50.77
	Left gunner right ear	148.3	0.52	-0.63	1.62	53.94
	Right gunner left ear	147.6	0.48	-0.61	2.58	52.38
	Passenger compartment - left	139.5	0.19	-0.24	2.30	69.53
	Passenger compartment - right	141.9	0.25	-0.22	5.75	80.53
RFRT05						
	Copilot left ear	149.8	0.62	-0.54	0.44	38.79
	Copilot right ear	151.4	0.74	-0.60	2.92	54.41
	Pilot left ear	154.5	1.06	-0.97	2.57	54.18
	Pilot right ear	154.4	1.05	-1.25	2.56	56.87
	Left gunner right ear	148.5	0.53	-0.55	4.79	69.64
	Right gunner left ear	148.0	0.50	-0.43	1.94	53.88
	Passenger compartment - left	139.1	0.18	-0.27	1.73	75.27
	Passenger compartment - right	140.8	0.22	-0.23	2.98	89.03

Table A-5.

Peak levels and durations during simultaneous deployment of the full ship-set cockpit airbags at the locations shown.

Test	Location	SPL (dB)	P-Peak (kPa)	N-Peak (kPa)	A-duration (ms)	B-duration (ms)
Full left						
	Copilot left ear	157.3	1.46	-1.51	7.97	92.80
	Copilot right ear	158.6	1.70	-1.91	6.31	70.16
Full right						
	Pilot left ear	160.6	2.14	-2.53	2.90	69.08
	Pilot right ear	161.3	2.31	-2.49	0.33	39.52
Full left and full right						
	Left gunner right ear	154.8	1.10	-1.29	5.97	88.08
	Right gunner left ear	156.6	1.36	-1.15	7.07	69.14
	Passenger compartment - left	147.2	0.46	-0.68	10.38	88.58
	Passenger compartment - right	147.6	0.48	-0.75	12.26	82.26

Appendix B.

CABS deployment pressure-time histories and peak impulse noise levels.
Figures B-1 through B-21

Note:
The waveforms were plotted using not less than ± 1.0 kPa to ± 3.0 kPa scaling.

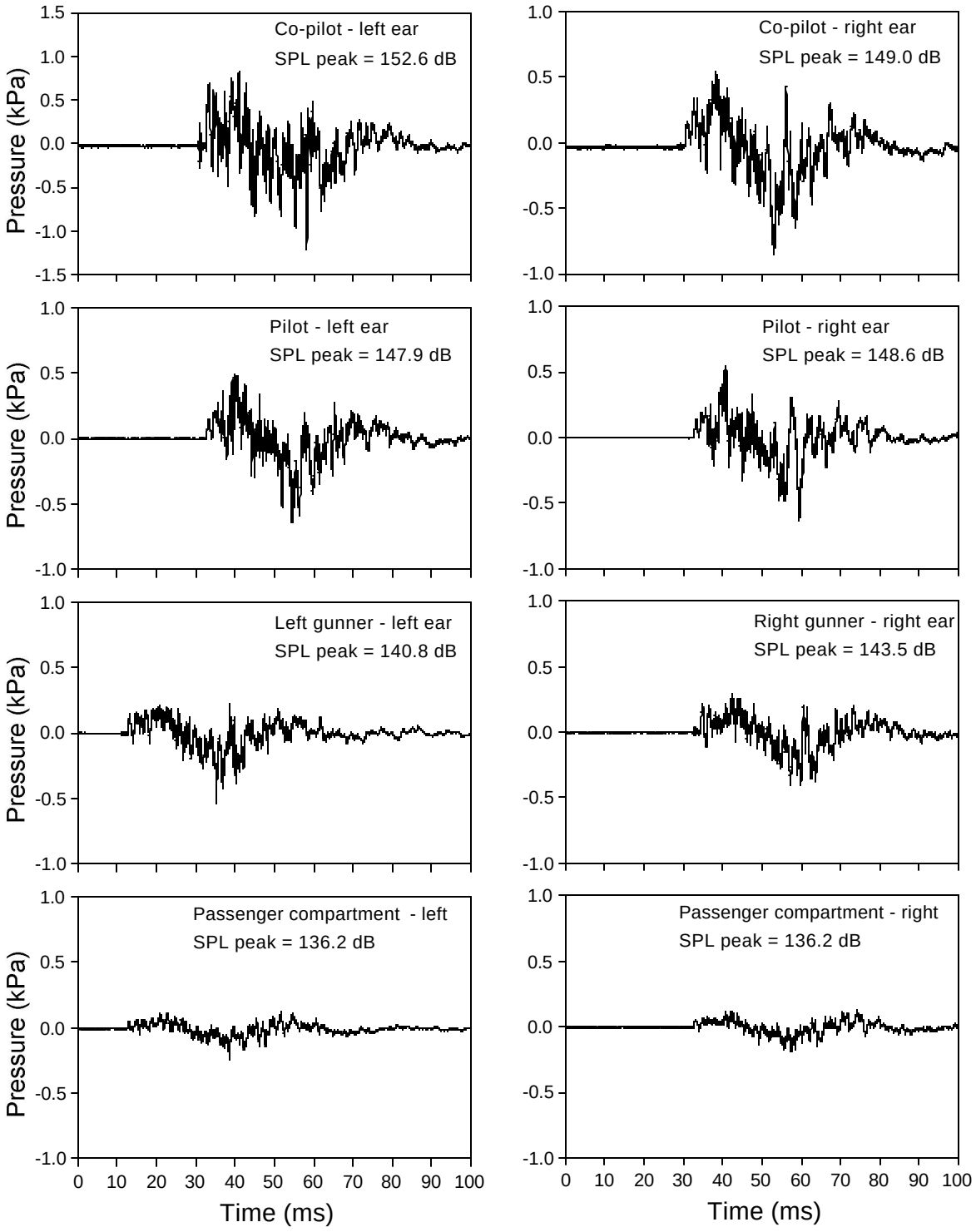

Figure B-1. LLAT01: Pressure-time histories and peak impulse noise levels – left lateral airbag deployment.

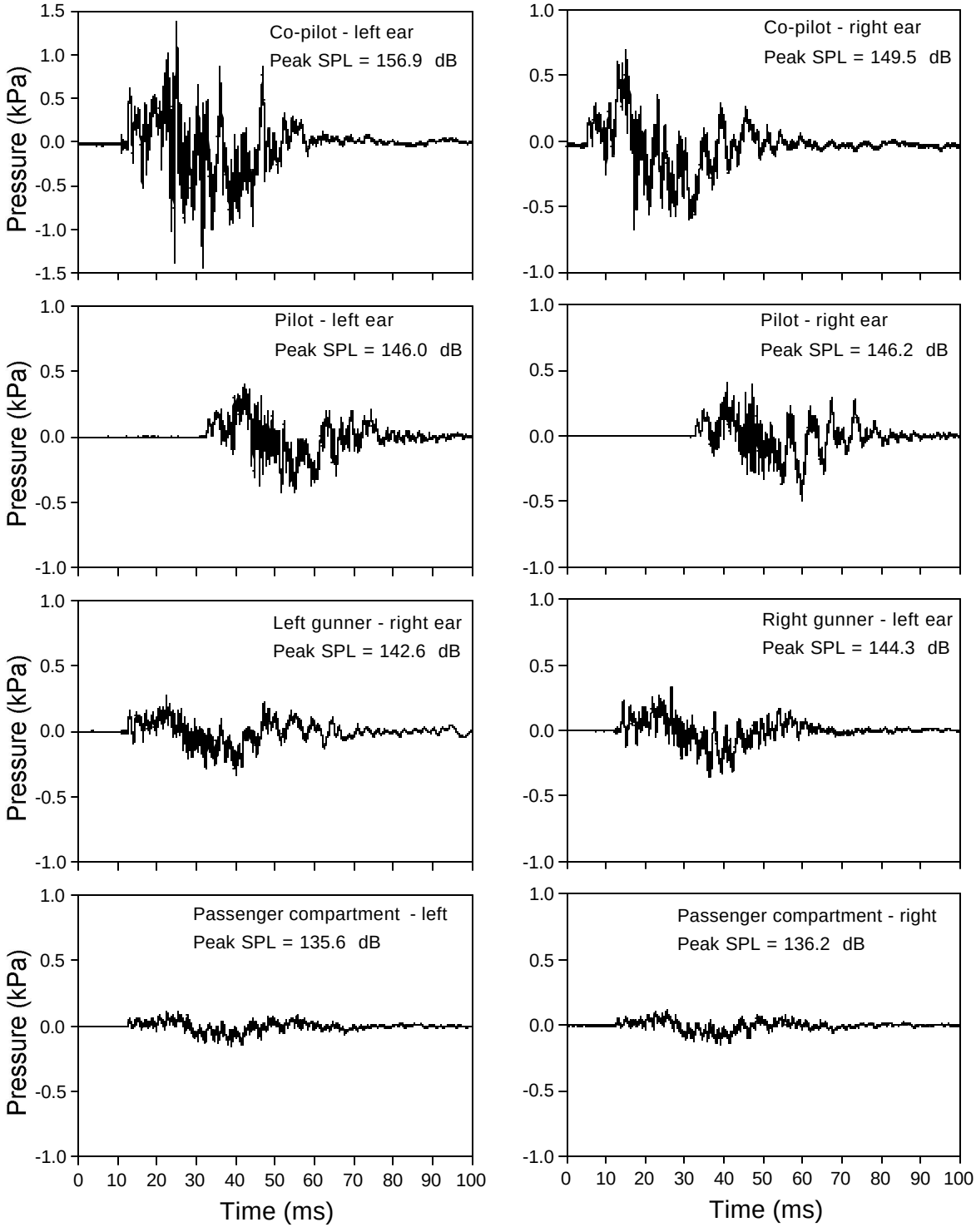

Figure B-2. LLAT02: Pressure-time histories and peak impulse noise levels – left lateral airbag deployment.

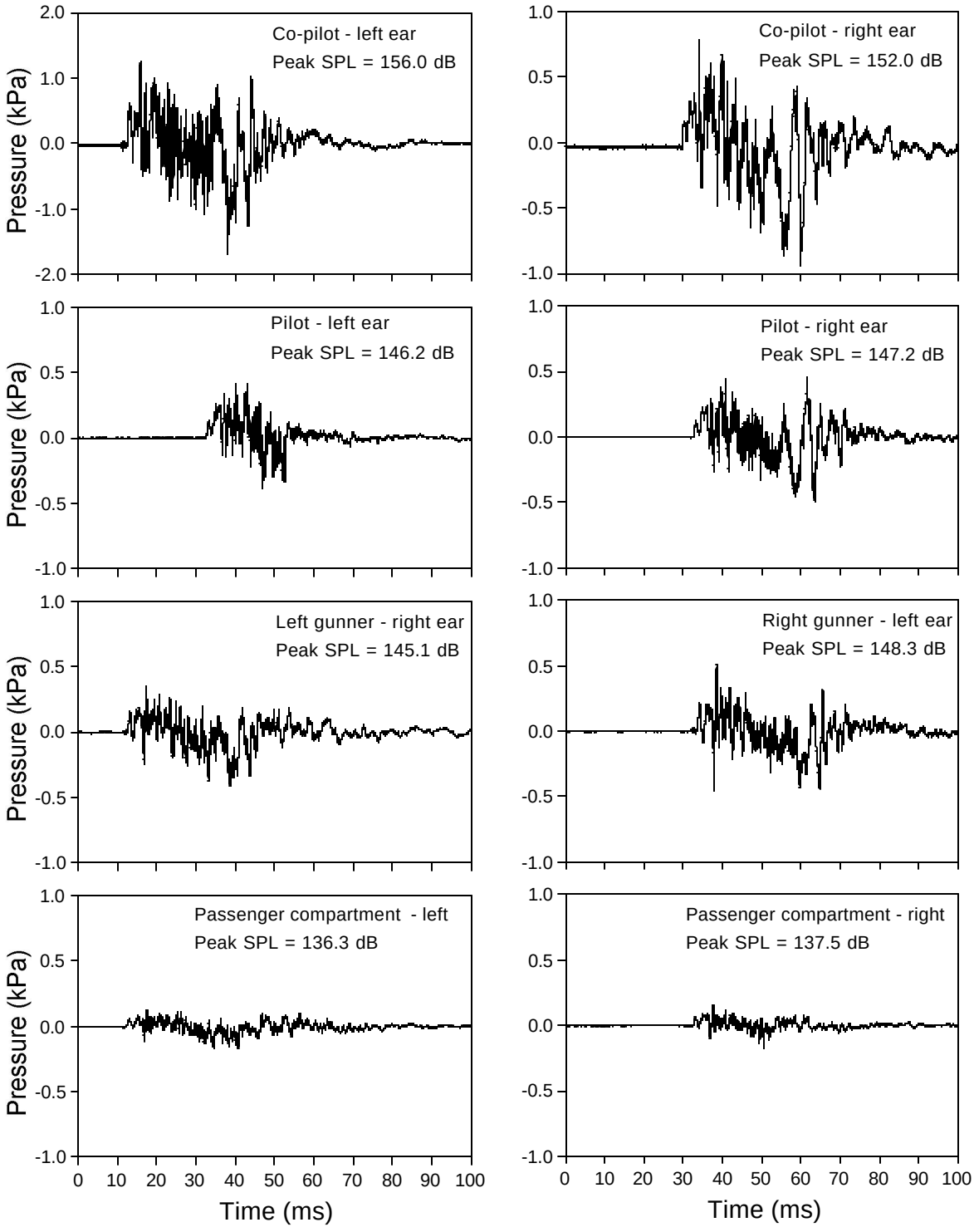

Figure B-3. LLAT03: Pressure-time histories and peak impulse noise levels – left lateral airbag deployment.

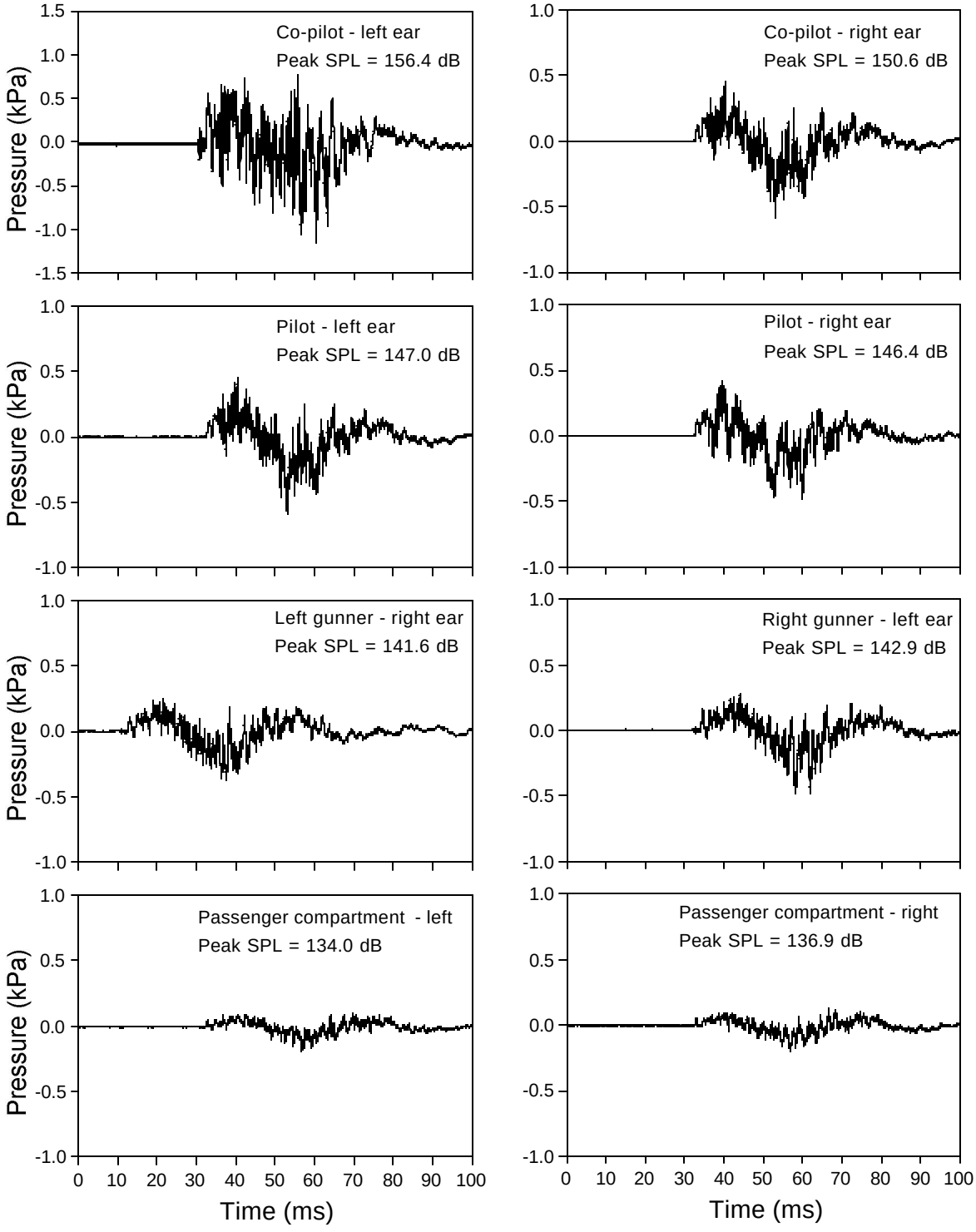

Figure B-4. LLAT04: Pressure-time histories and peak impulse noise levels – left lateral airbag deployment.

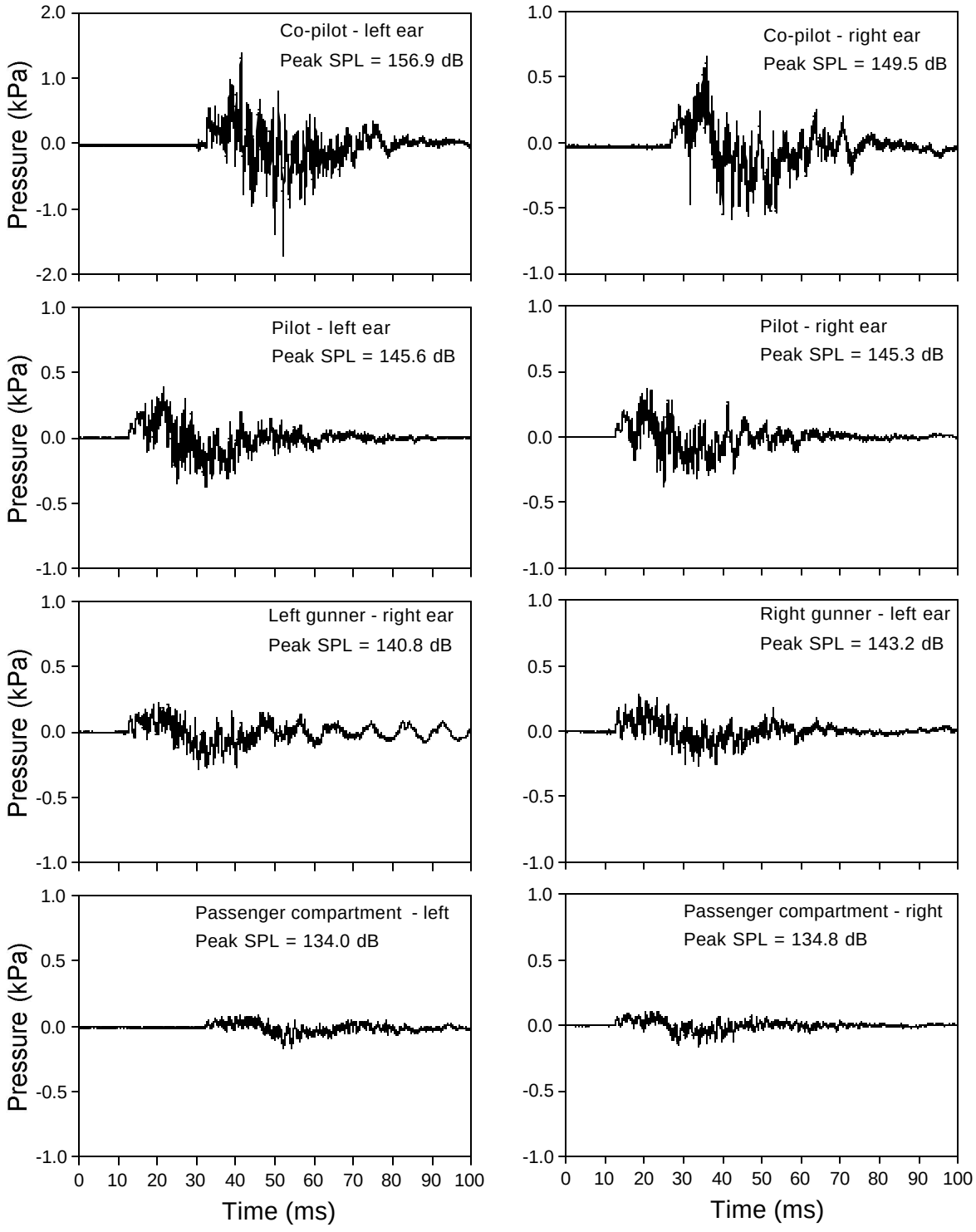

Figure B-5. LLAT05: Pressure-time histories and peak impulse noise levels – left lateral airbag deployment

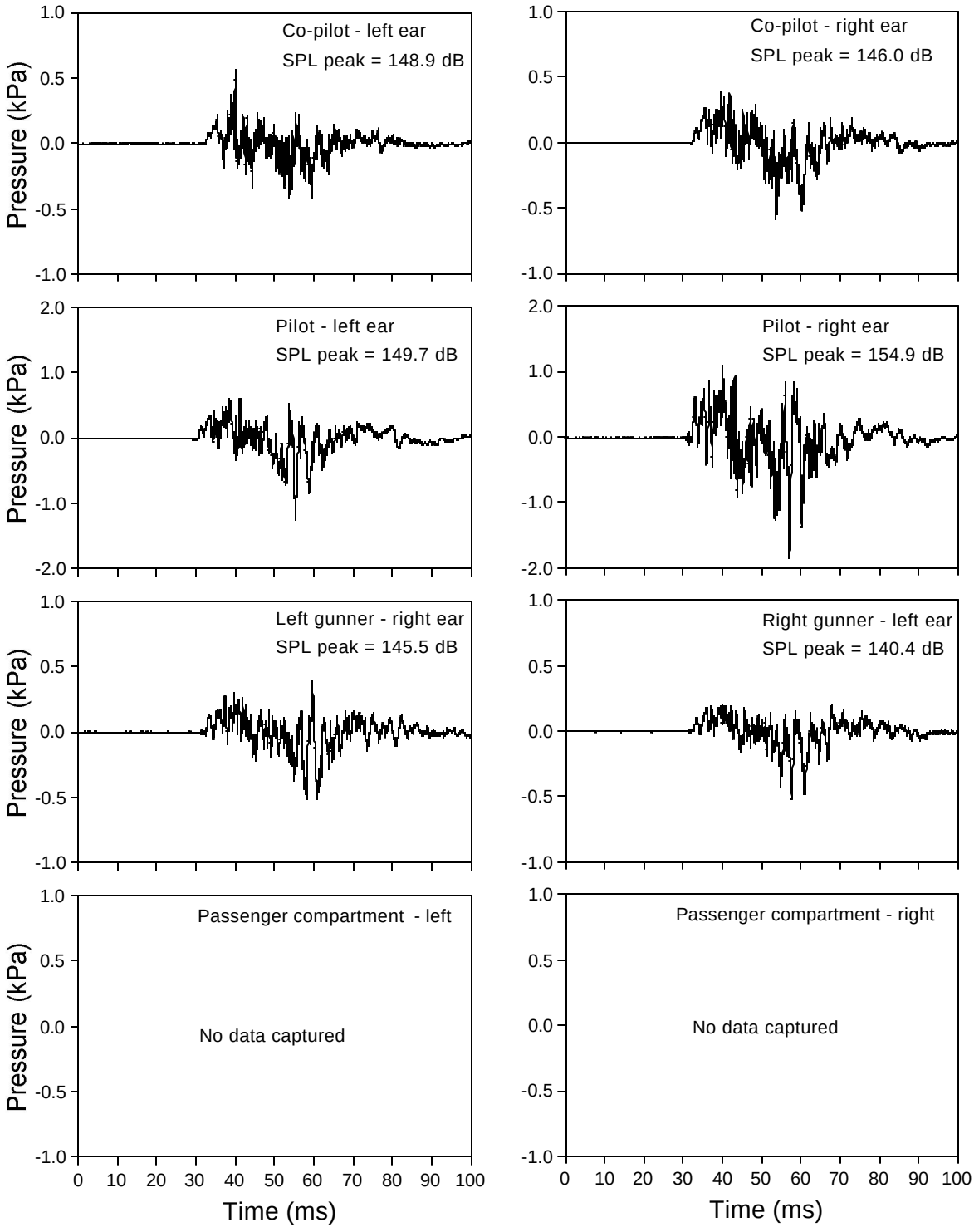

Figure B-6. RLAT01: Pressure-time histories and peak impulse noise levels – right lateral airbag deployment

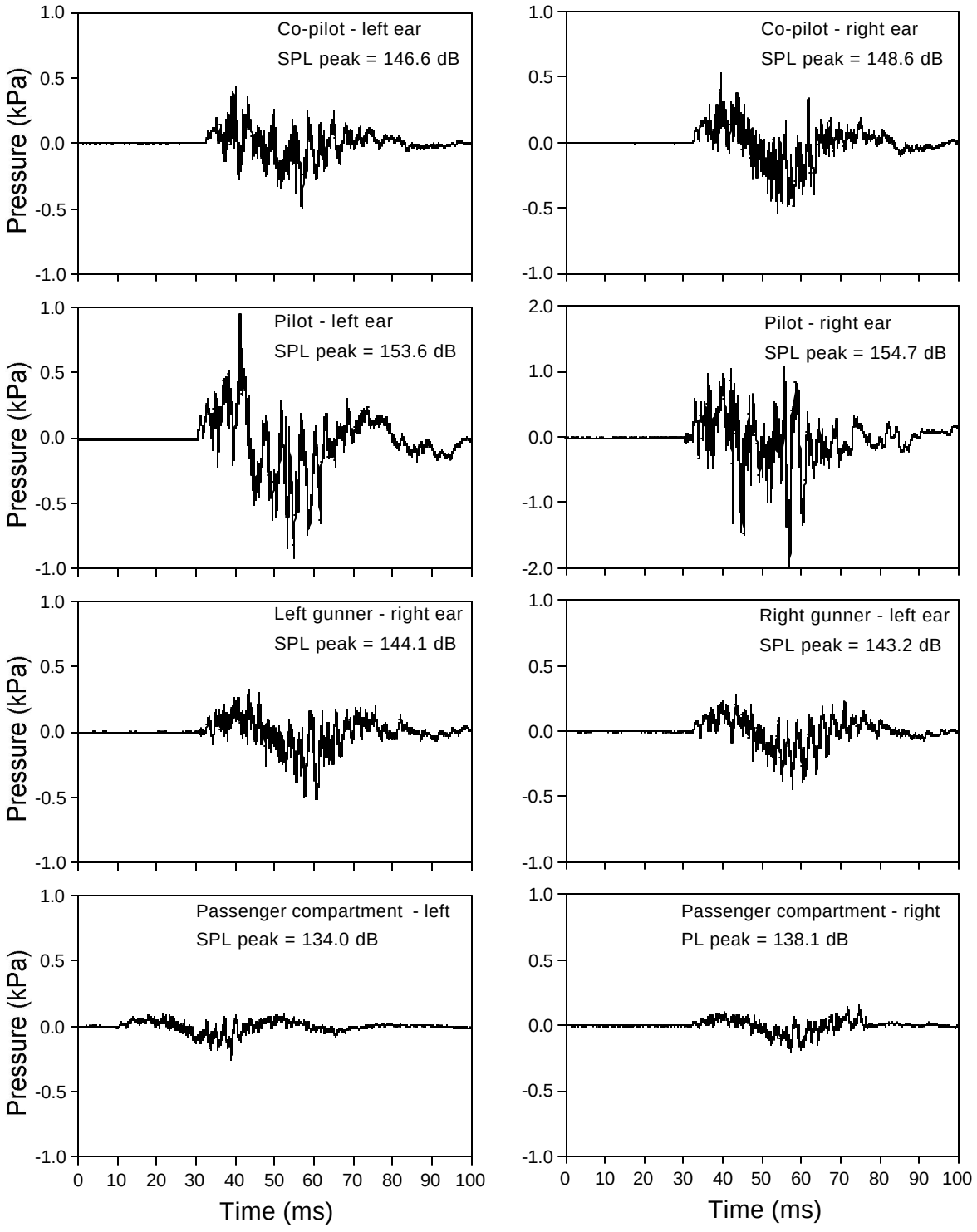

Figure B-7. RLAT02: Pressure-time histories and peak impulse noise levels – right lateral airbag deployment

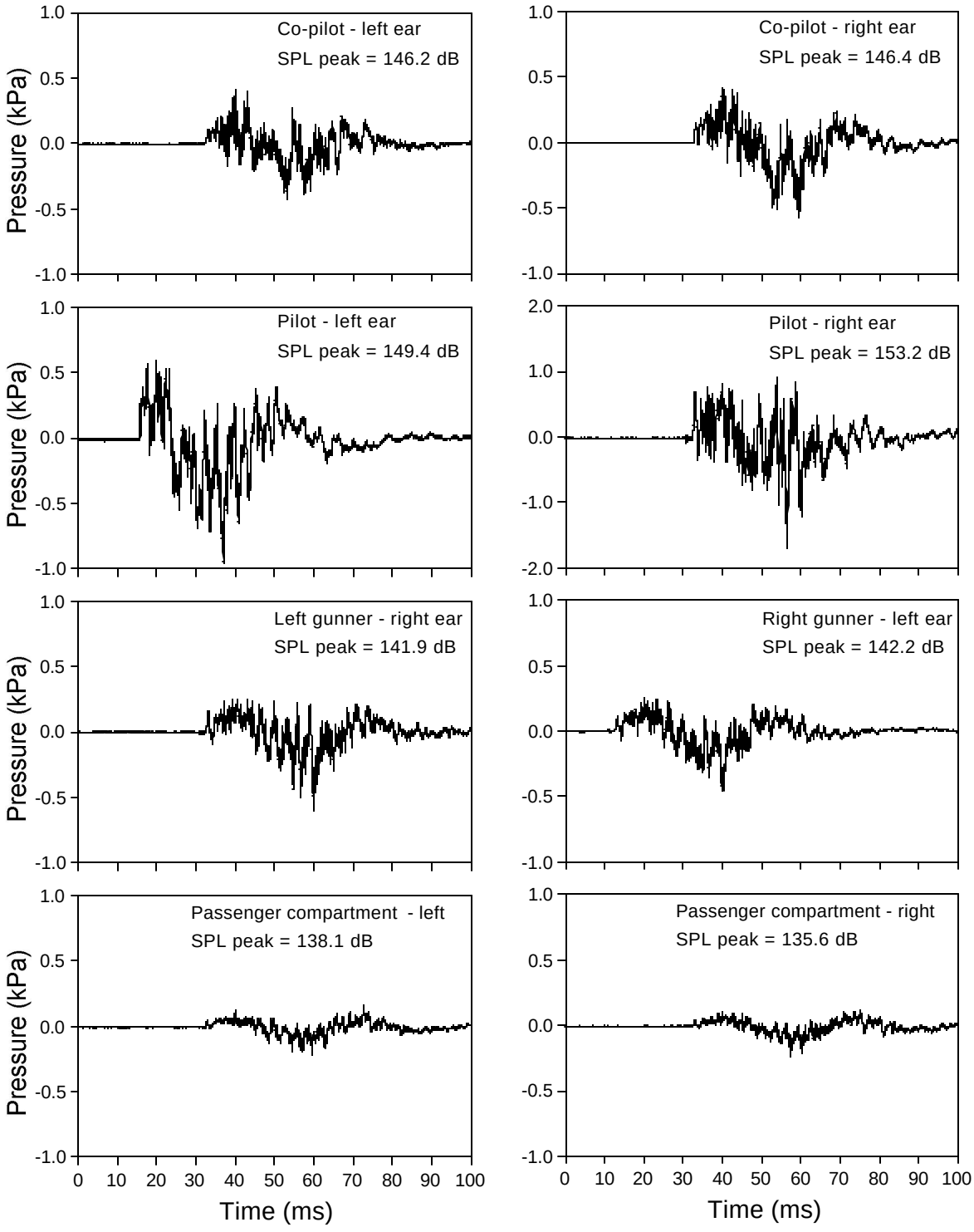

Figure B-8. RLAT03: Pressure-time histories and peak impulse noise levels – right lateral airbag deployment.

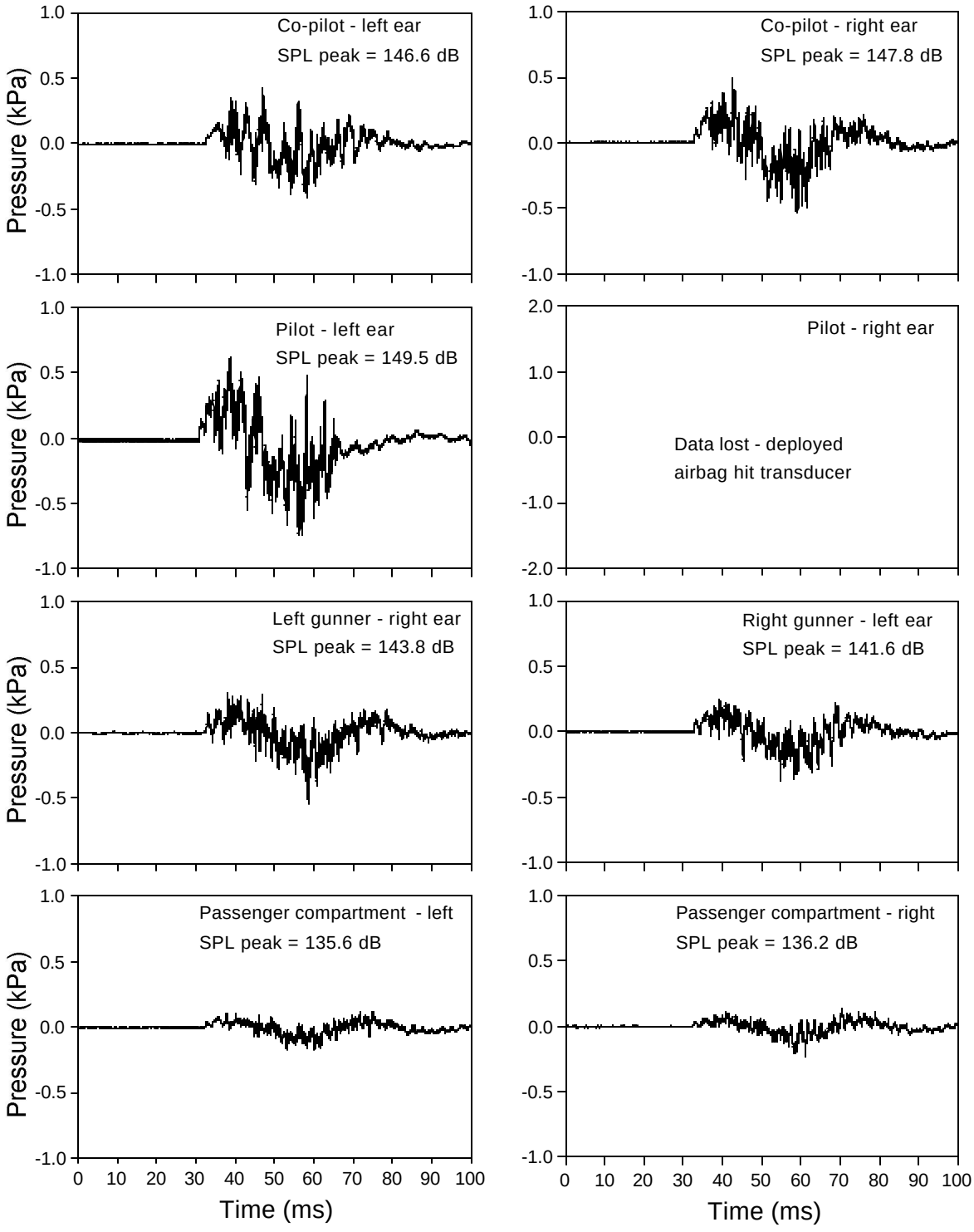

Figure B-9. RLAT04: Pressure-time histories and peak impulse noise levels – right lateral airbag deployment.

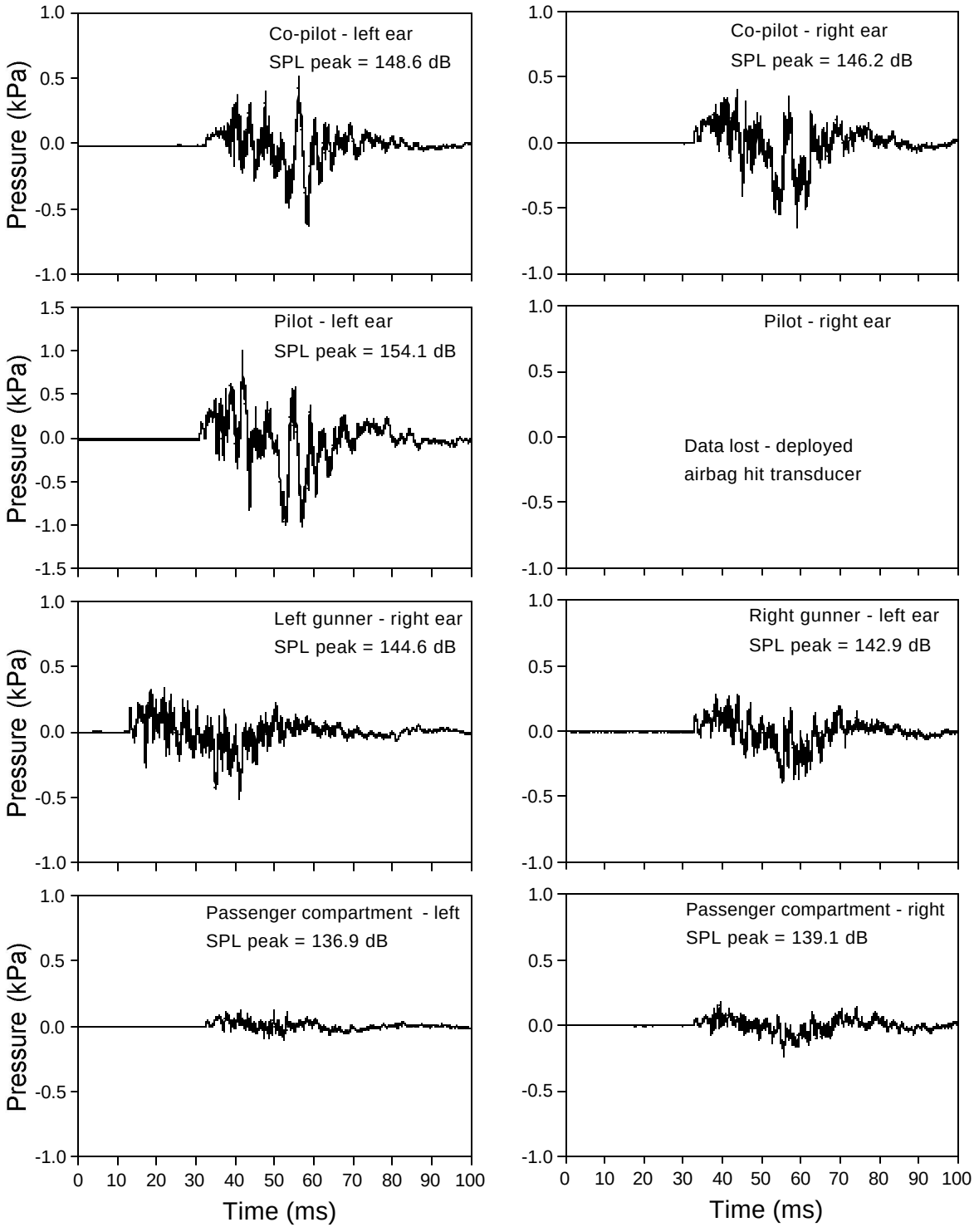

Figure B-10. RLAT05: Pressure-time histories and peak impulse noise levels – right lateral airbag deployment.

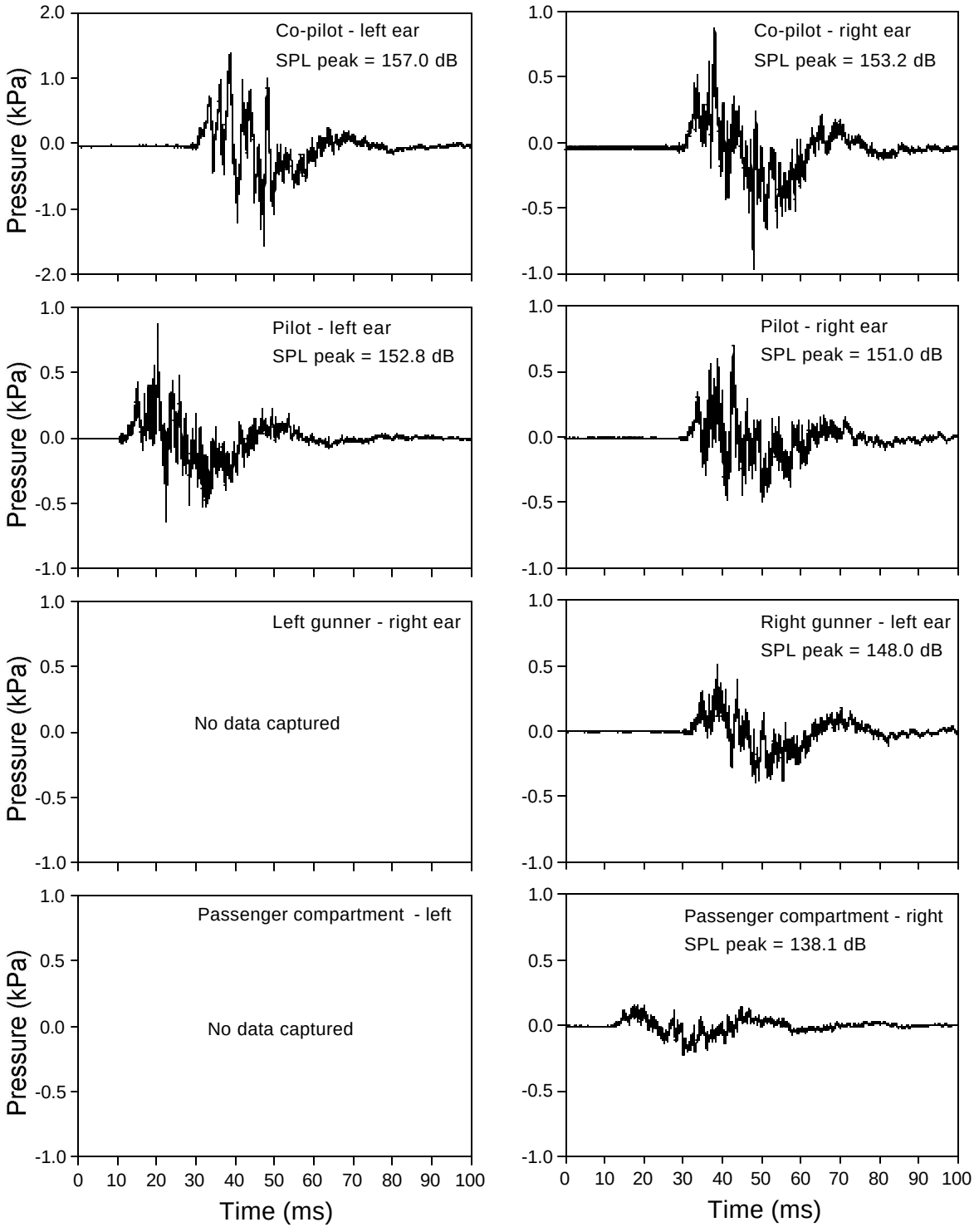

Figure B-11. LFRT01: Pressure-time histories and peak impulse noise levels – left front airbag deployment.

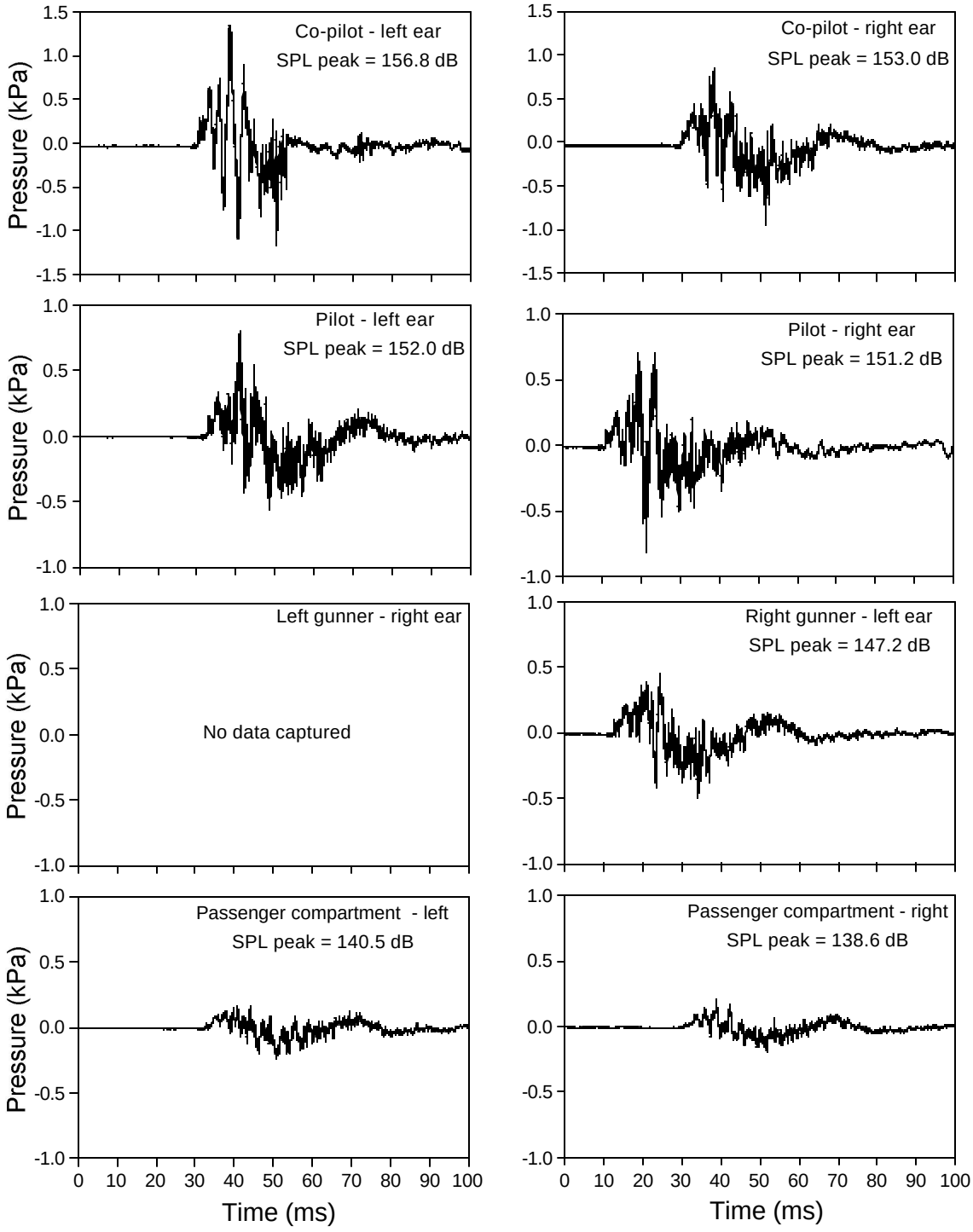

Figure B-12. LFRT02: Pressure-time histories and peak impulse noise levels – left frontal airbag deployment.

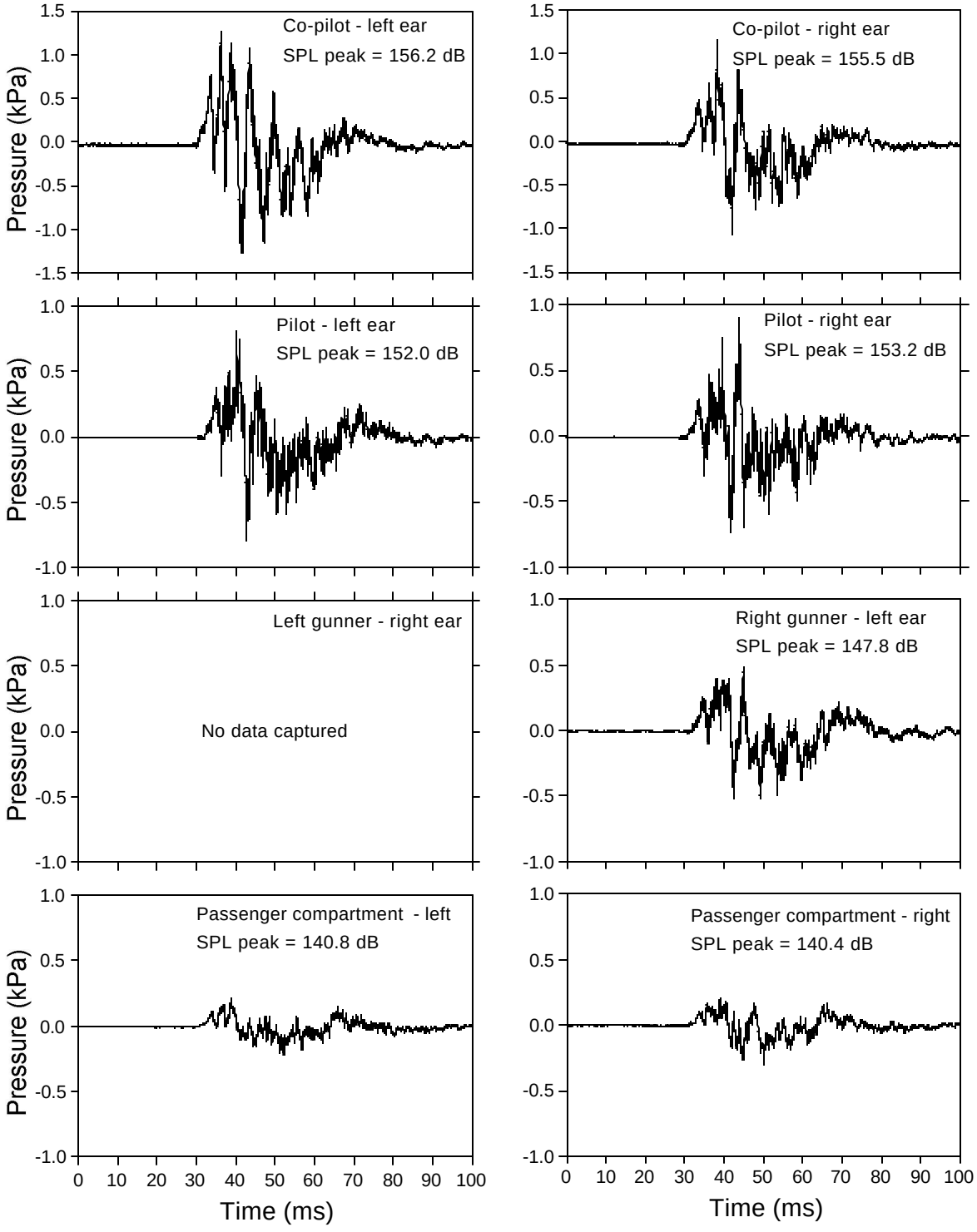

Figure B-13. LFRT03: Pressure-time histories and peak impulse noise levels – left frontal airbag deployment.

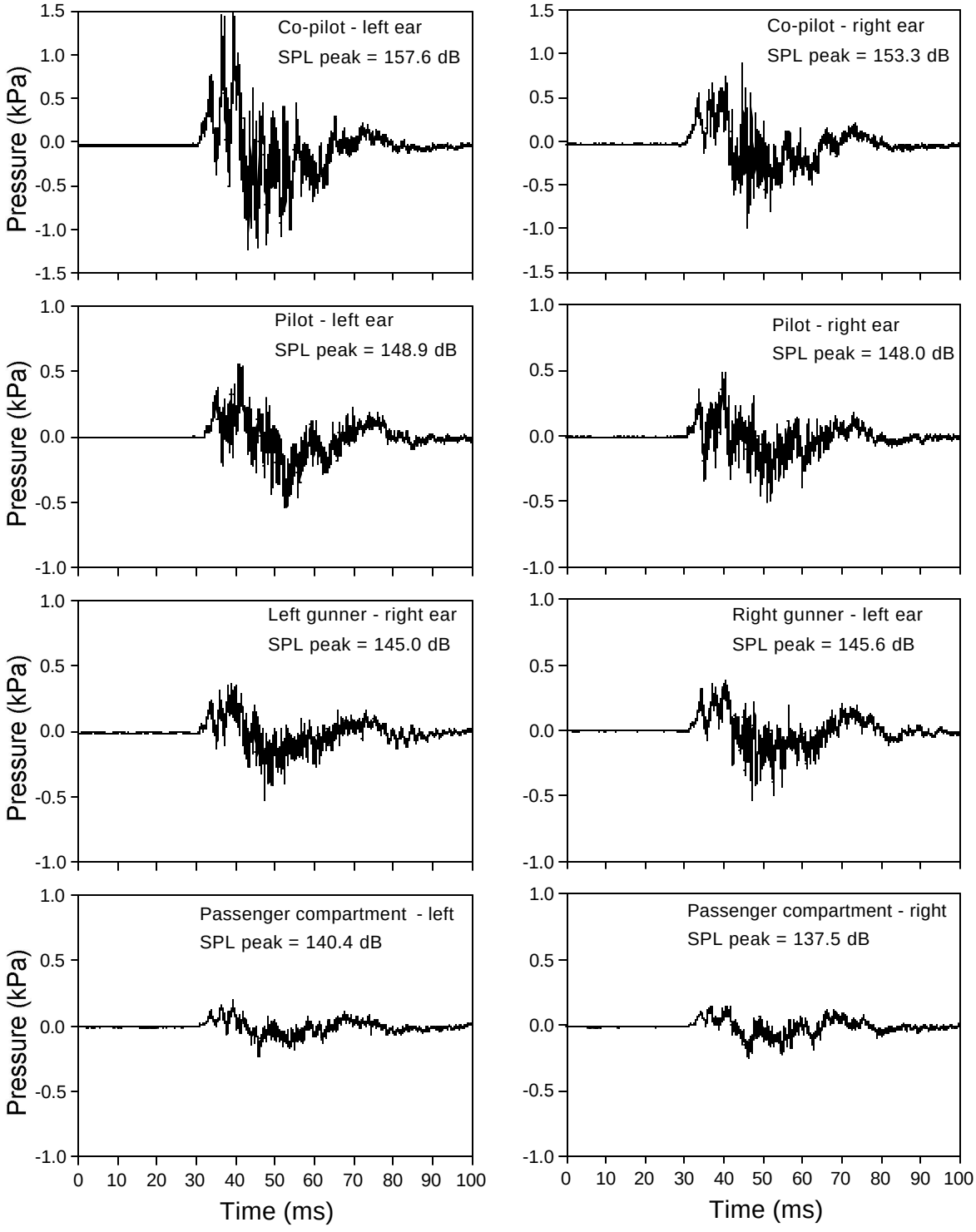

Figure B-14. LFRT04: Pressure-time histories and peak impulse noise levels – left frontal airbag deployment.

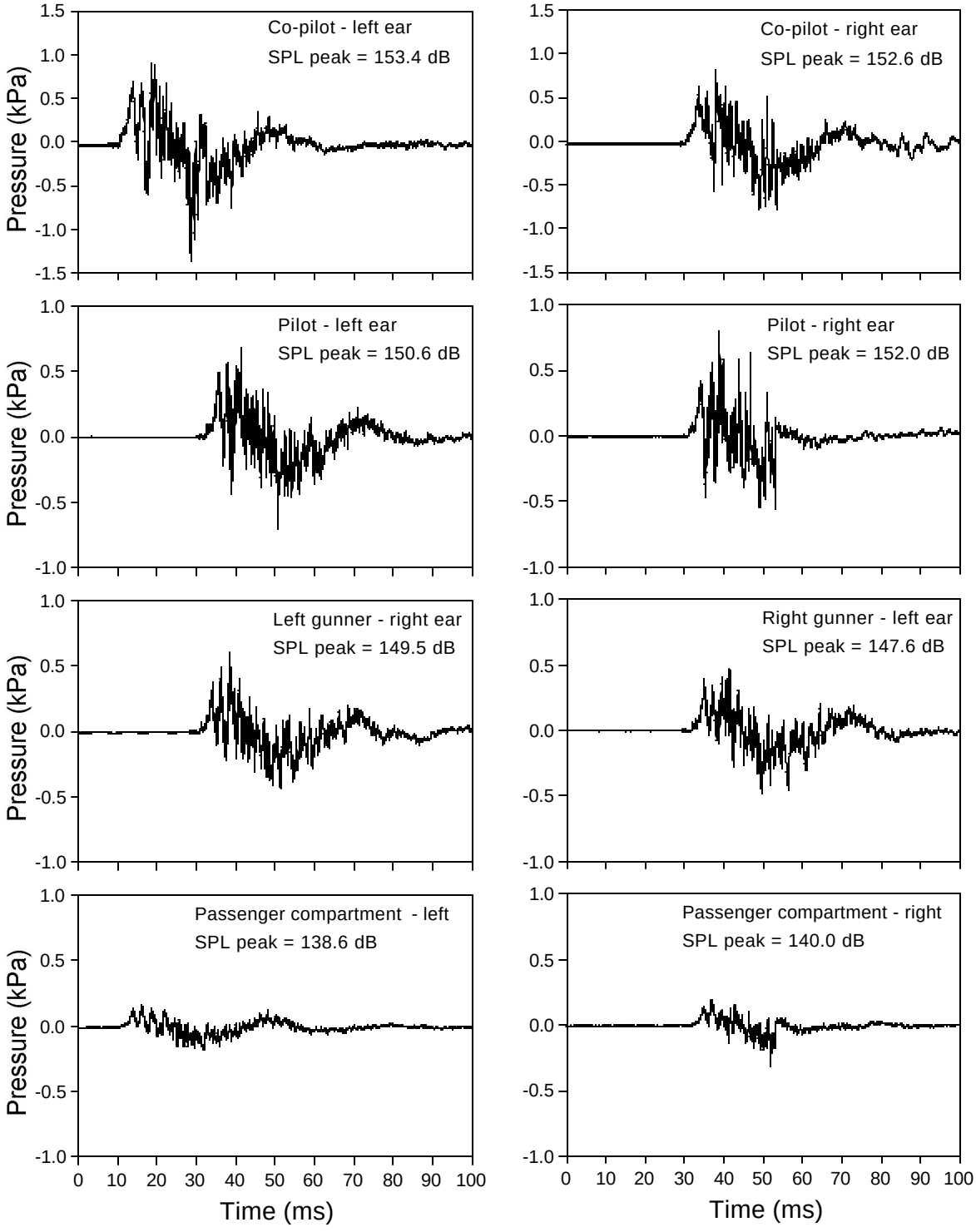

Figure B-15. LFRT05: Pressure-time histories and peak impulse noise levels – left frontal airbag deployment

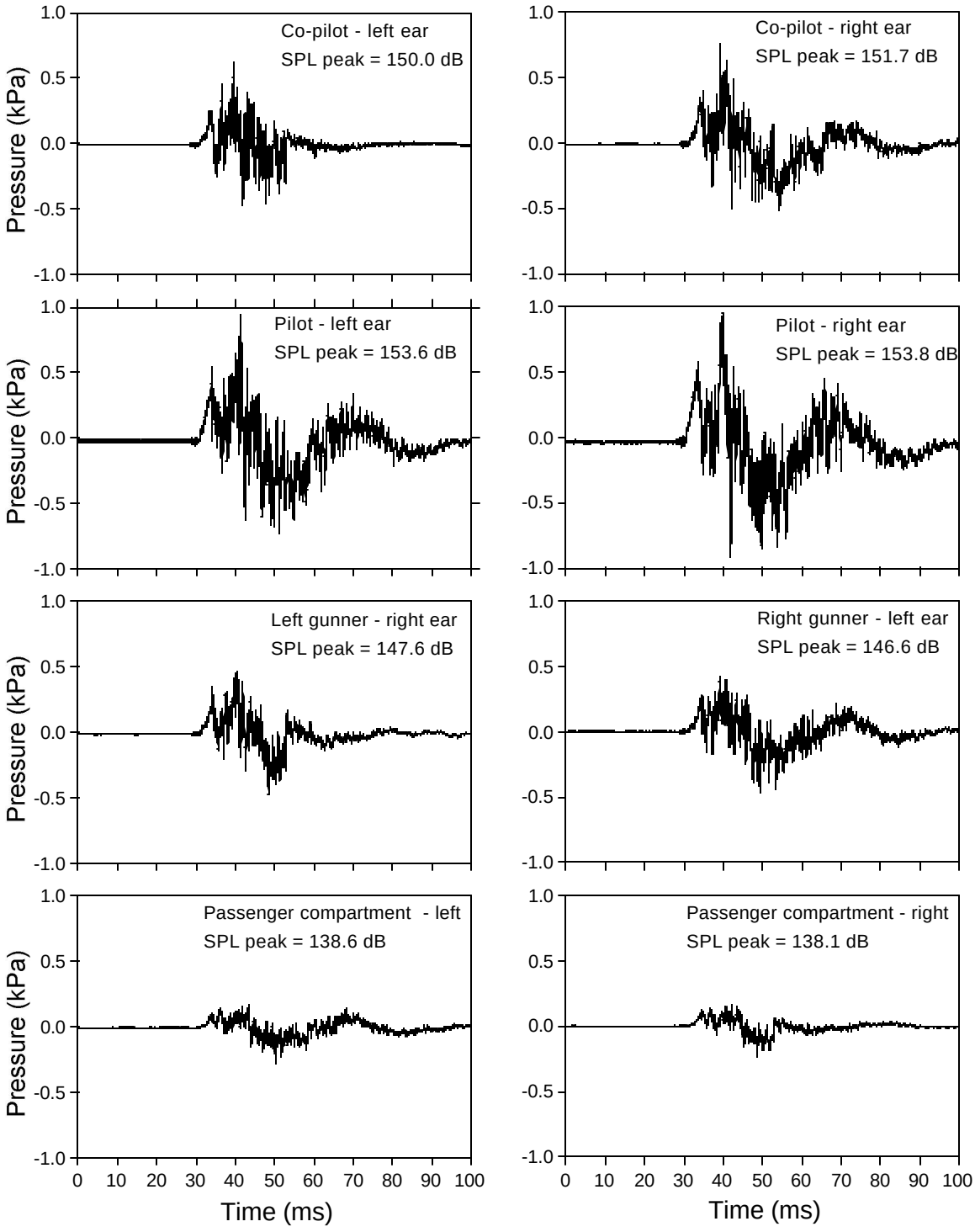

Figure B-16. RFRT01: Pressure-time histories and peak impulse noise levels – right frontal airbag deployment.

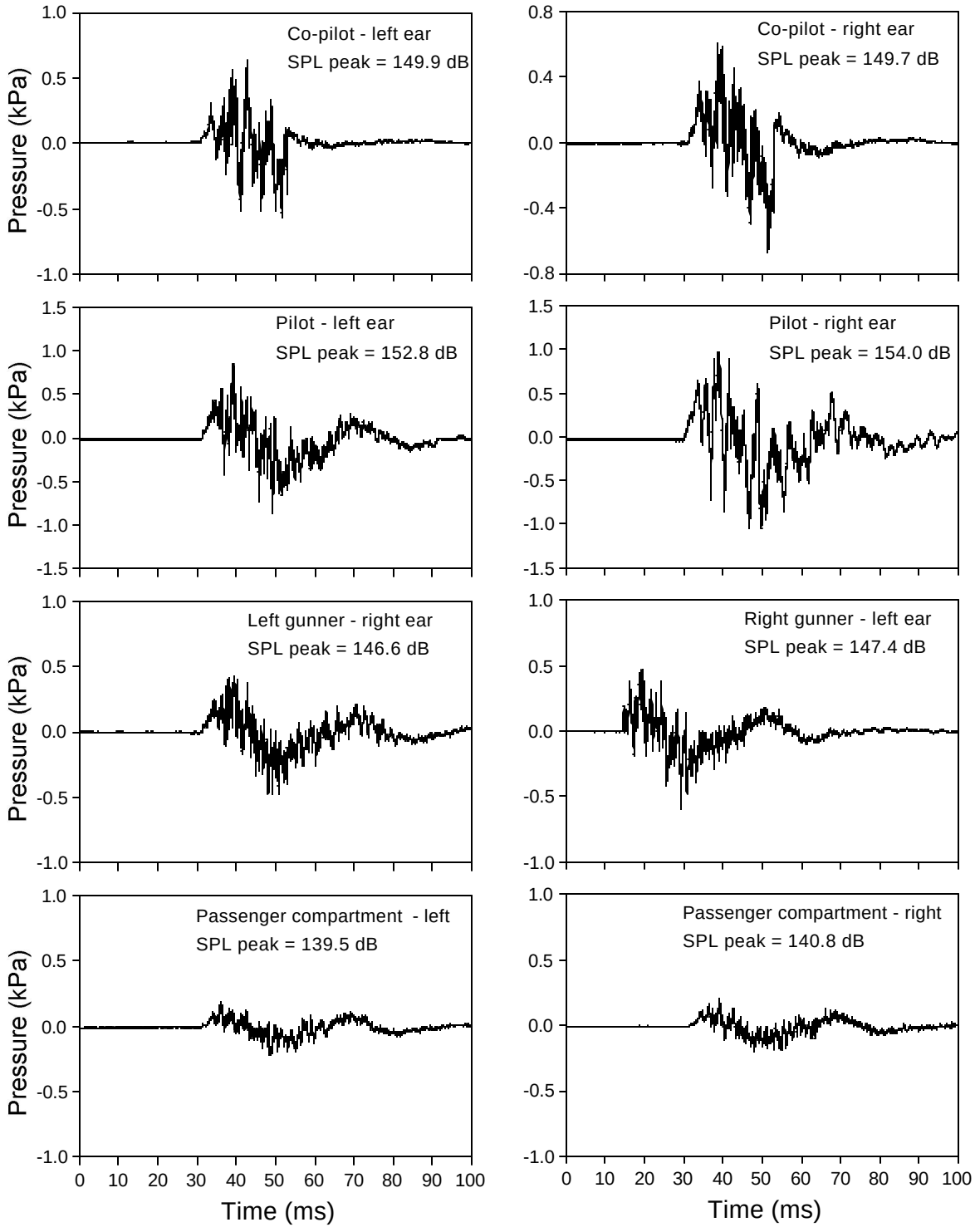

Figure B-17. RFRT02: Pressure-time histories and peak impulse noise levels – right frontal airbag deployment.

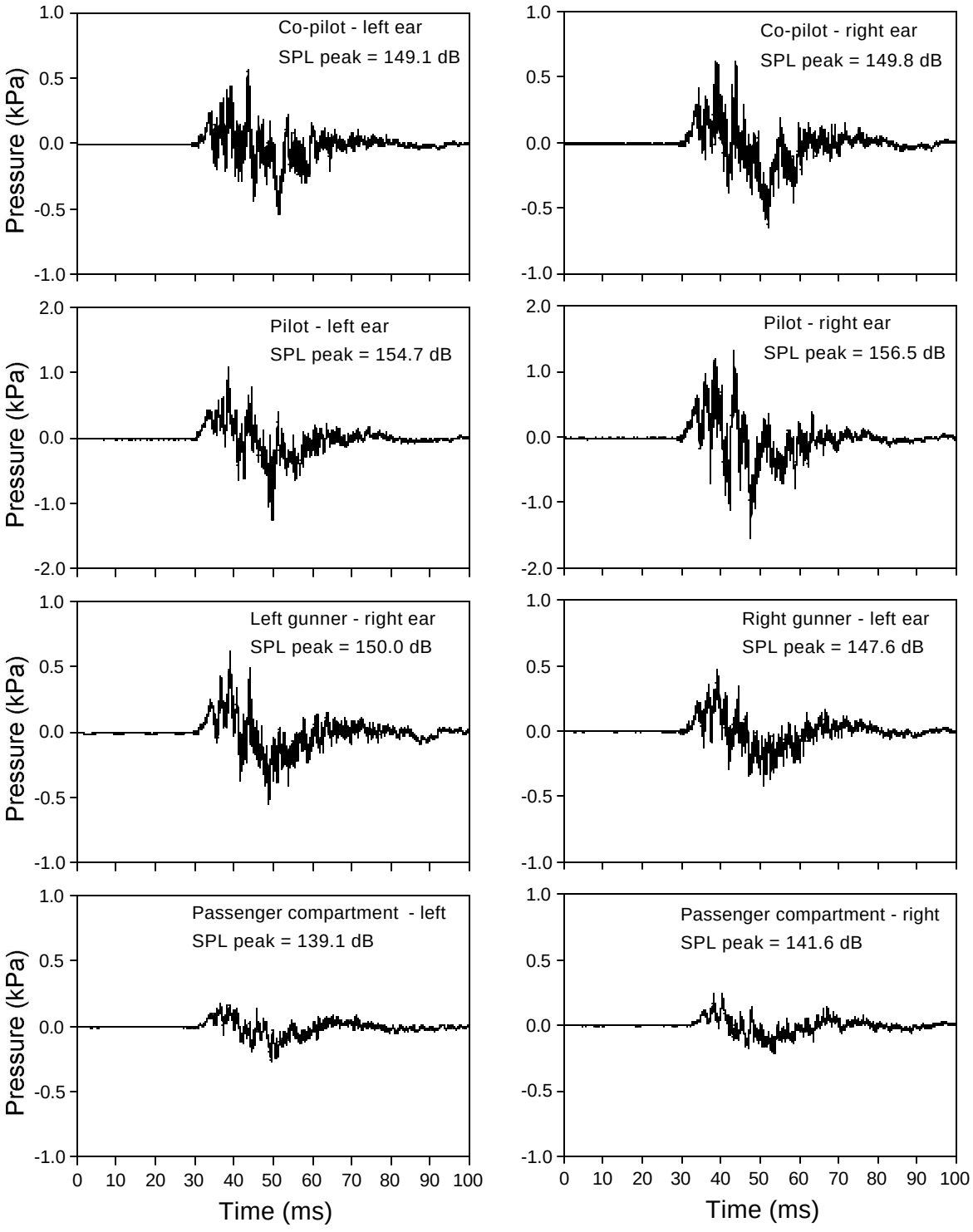

Figure B-18. RFRT03: Pressure-time histories and peak impulse noise levels – right frontal airbag deployment.

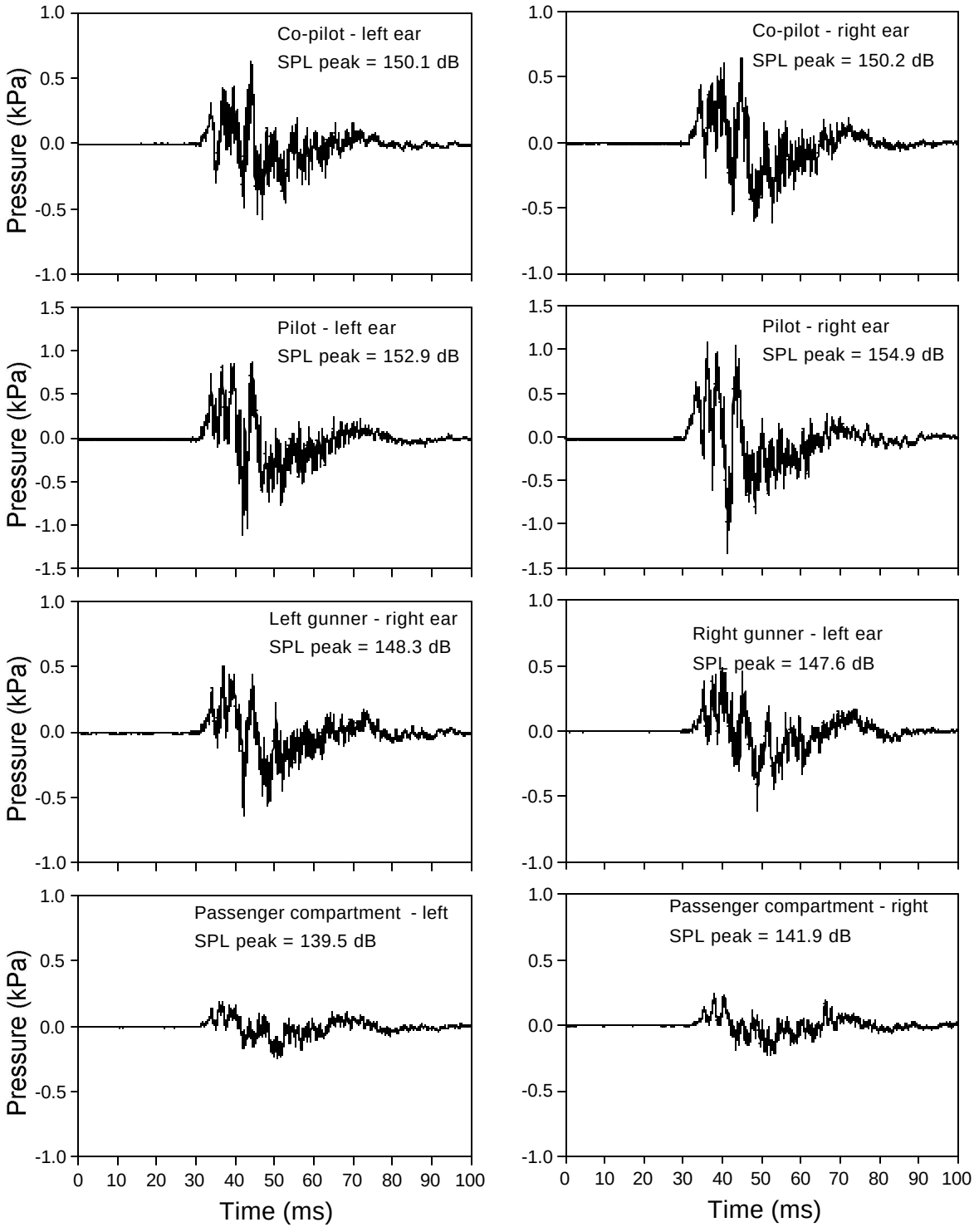

Figure B-19. RFRT04: Pressure-time histories and peak impulse noise levels – right frontal airbag deployment.

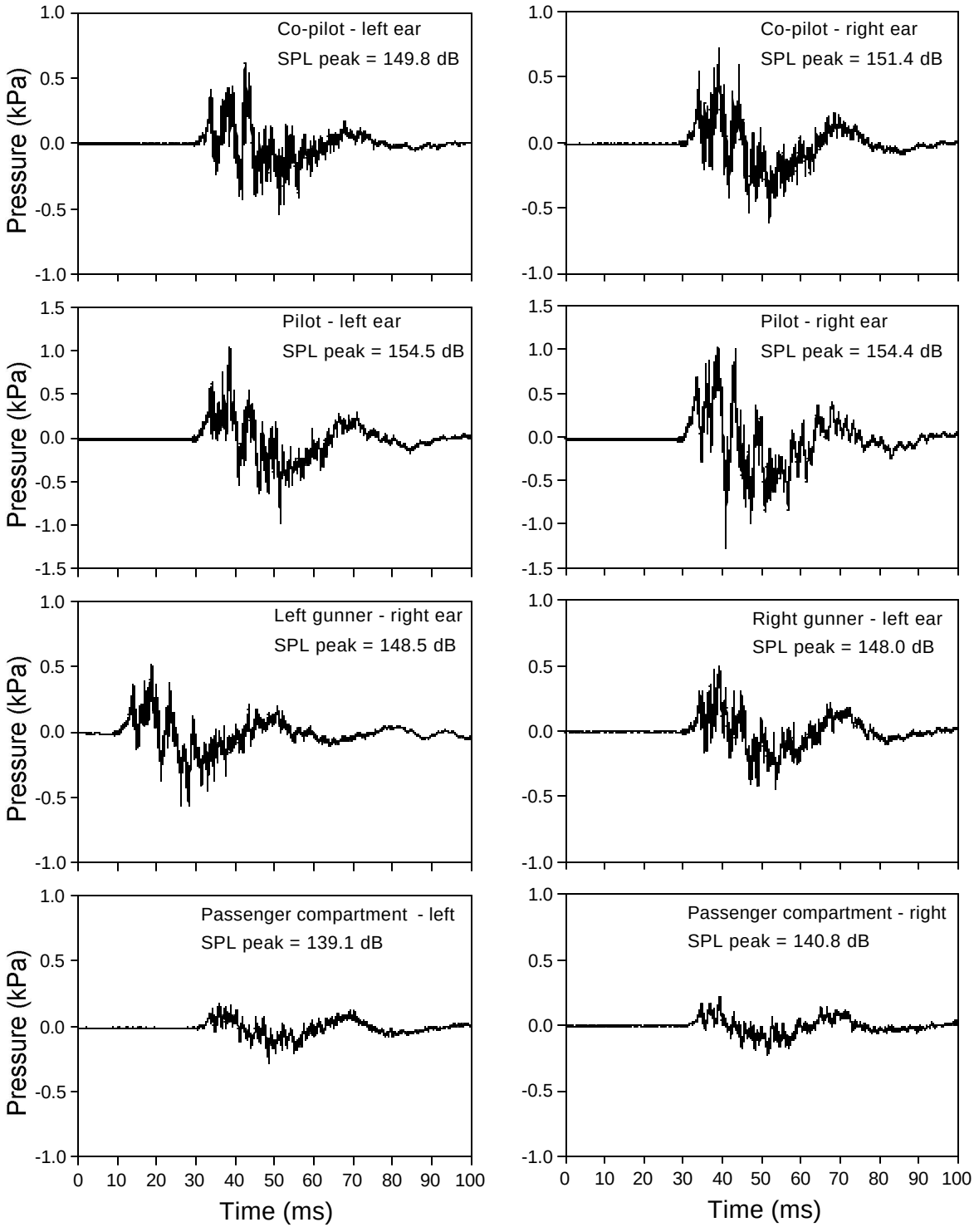

Figure B-20. RFRT05: Pressure-time histories and peak impulse noise levels – right frontal airbag deployment.

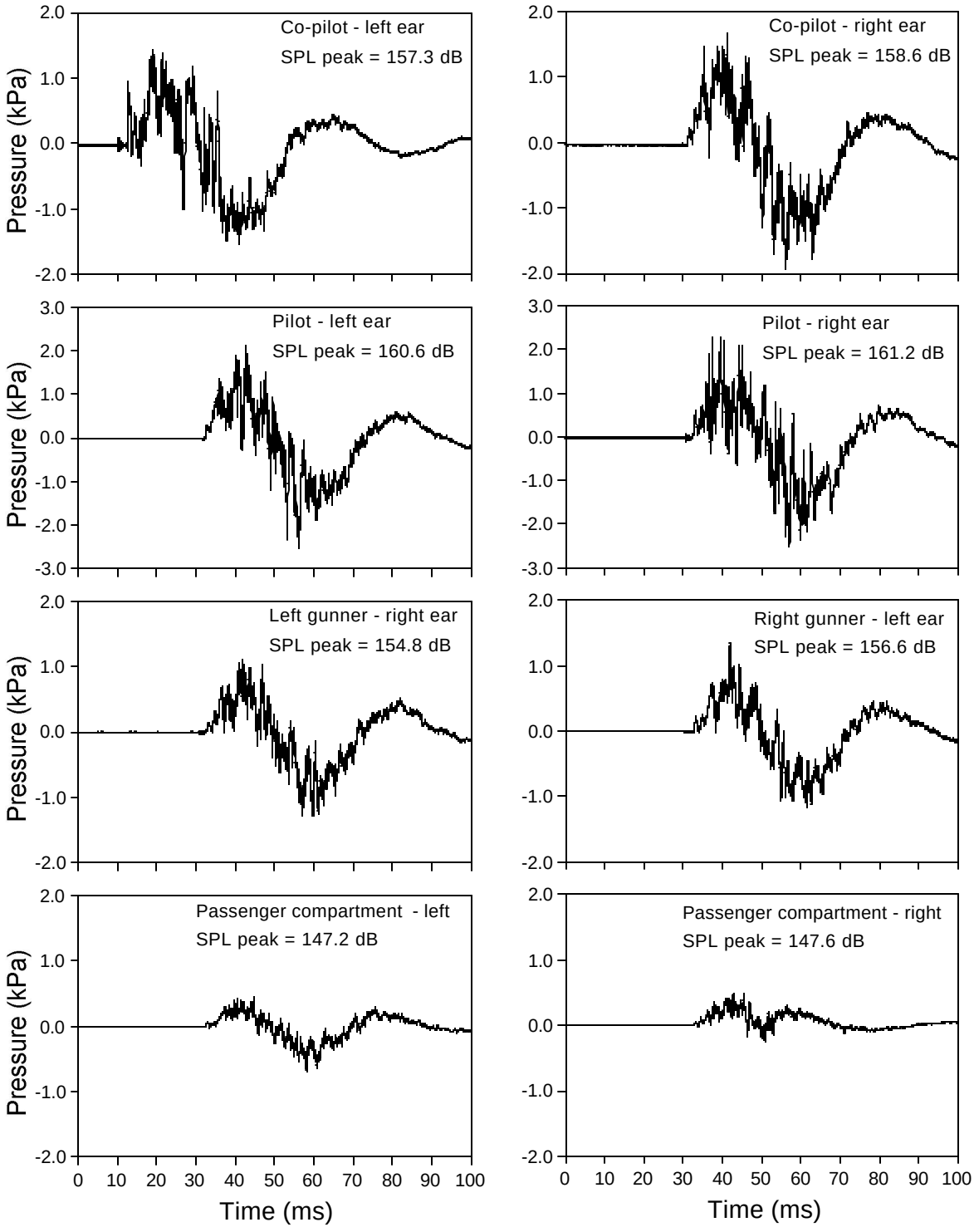

Figure B-21. LEFT FULL and RIGHT FULL: Pressure-time histories and peak impulse noise levels – full ship-set (left and right, lateral and frontal airbags) deployments.