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THE LANDING SIGNAL OFFICER: AUDITORY ASPECTS

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NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA FLORIDA

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SUMMARY PAGE

THE PROBLEM

Landing signal officers (LSOs), who are exposed to high noise levels in the execution of their duties during carrier air operations, do not routinely wear any hearing protective device. Noise measurements and noise exposure data are needed in order to determine whether such exposures can, over time, produce significant noise-induced hearing loss.

FINDINGS

Noise measurement data and noise exposure data obtained during carrier qualifications on board the USS Lexington (AVT-16) and the USS Forrestal (CVA-59) confirm a potential damage risk to hearing. The wearing of hearing protective devices is presently the only reasonable way to control the LSO's exposure to noise.

Questionnaire data from 225 LSOs indicate that for optimal safety and management of carrier landings under all acoustical conditions, it is necessary for the LSO to have full access to aircraft auditory cues, not attainable with currently available off-the-shelf hearing protective devices.

A comparison of average hearing threshold levels for LSOs and non-LSO pilots, matched for age and number of flight hours, indicates a trend for poorer hearing thresholds by the LSOs.

RECOMMENDATIONS

An active type hearing protective device should be developed for the LSO, one which would permit passage of critical auditory cues and, at the same time, provide adequate hearing protection. In conjunction with such a development should be a redesign of the UHF handset. Particular emphasis should be placed on the use of a superior noise-cancelling microphone and an earpiece designed to give good noise rejection when combined with the new protector.

Further hearing threshold level studies of LSOs and non-LSO pilots should be undertaken on a larger scale.

ACKNOWLEDGMENTS

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Mr. Maxwell, at the time of this investigation, was with the Hearing Conservation Service, Naval Aerospace Medical Institute. He is currently with the Hearing Conservation Branch, Navy Environmental Health Center (Pensacola).

INTRODUCTION

While obtaining field data aboard the USS Ranger concerning the adequacy of flight deck headgear relative to hearing protection (5), the principal investigator became aware of the intense noise levels present at the landing signal officer's (LSO) position. Noise measurements indicated transient (1-2 sec) levels of approximately 120 dBA as aircraft passed abeam the LSO platform and higher levels during wave-offs as aircraft passed almost directly above the LSO platform at full power. These noise levels were superimposed on ambient noise levels on the flight deck of approximately 100-110 dBA throughout operational periods. Levels of such magnitude could, over time, produce significant noise-induced hearing loss. More specific and thorough noise exposure data were felt to be necessary before an absolute statement could be made concerning the potential damage risk to hearing.

Landing signal officers do not routinely wear hearing protective devices. As stated in a recent naval aviation publication (1), "Ears are not worn because LSOs need to hear aircraft power changes to assist them in analyzing aircraft glide slopes. Also, they need to talk to each other to grade passes." Usually the only attenuation of ambient noise is afforded by a telephone-type handset used by the LSO to communicate with the pilot of the aircraft on closest approach. Generally then, one ear is partially protected and the other ear is completely unprotected.

Subsequent to data gathering aboard the USS Ranger, a continuation of the flight deck headgear study was carried out on the USS Lexington. At this time another opportunity was taken to talk with the LSOs and to observe them at their work station. In addition, an "active" hearing protective device, the Cosmocord Eardefender, was taken aboard for trial and comments by the LSOs. This device, which was developed in the United Kingdom, is basically a circumaural hearing protective device with a microphone built into each ear cup, receivers at the ear, and a battery case with switch situated on top of the headband. The unit permits sound stimuli to reach the ear at a predetermined level which can be adjusted. Under present damage risk standards this level would be 90 dBA. If ambient noise exceeds the selected level, the basic attenuation characteristics of the circumaural ear cups take over, providing sound reduction as any other "ear muff" would.

Informal discussions with several LSOs after they had tried the Eardefender produced favorable comments overall. Most LSOs felt that the concept was good but that the device was too heavy. (Cosmocord has since changed the design of the unit and lightened it.)

Divergent opinions were expressed among the LSOs relative to the extent to which they use auditory information in assessing pilot/aircraft approach performance. While some individuals said that hearing the aircraft was imperative, others stated that very often during carrier qualifications they could not hear the aircraft even if they wanted to, due to the high ambient noise levels in the FLY 1 and FLY 2 areas; other LSOs said that compared to visual cues, auditory cues were relatively unimportant.

LITERATURE REVIEW

The first systematic study of LSO problem areas was conducted by Borden (2). Borden utilized a mail questionnaire as his primary data collection tool, along with discussions, conferences, and interviews. The overall problem identified from data in the Borden study was that the type and manner of information displays available to the LSO were inadequate. A review of those data from the Borden study that are primarily related to auditory aspects will serve as background for the study reported here.

The sound of the engine was identified as the prime cue for the power control parameter of aircraft performance. It was noted that engine sound is also used to judge "rate of descent" and "speed control" but it is not the prime cue for these factors; respondents ranked engine sound approximately fourth for judging rate of descent and speed control. The following data (2) indicate the percentage of LSOs mentioning "sound of the engine" as a cue for power control for the conditions indicated:

Deviation from optimum approach during day and night recovery operations:

Day - 86.7%	Night - 79.5%

Changes in the approach during day and night recovery operations:

Day - 78.3%	Night - 71.1%

The less dependence on auditory cues at night is an unusual finding. While perhaps not statistically significant, the trend is interesting.

LSOs rated the order of importance of five pilot/aircraft performance parameters for accomplishing a safe and successful recovery. Ratings were obtained by having the LSOs assign numeric values to each of the five parameters. A rating of 5.0 was defined as most important. The parameters identified and their order of importance were as follows:

1. Glide slope
2. Line-up
3. Power
4. Attitude
5. Speed

Not only did this rank ordering hold for both day and night recoveries, but also the numeric values assigned were of the same magnitude. The range of values assigned was from 4.7 for glide slope to 1.9 for speed.

Deviations from optimum performance or changes in approach performance as discerned by the LSO are based upon the above-listed parameters. According to Borden, "Deviation from optimal performance requires the LSO to judge whether or not the pilot/aircraft performance parameters have deviated from an optimum state and to judge the degree of deviation from optimum. For example, the LSO must judge whether or not the aircraft is properly lined up. The latter task requires the LSO to judge whether or not the pilot/

aircraft performance parameters have changed, or are changing regardless of whether they are optimum. For example, the LSO must judge whether line-up has changed or is changing from its immediately preceding state" (2).

The parameters were not all equally easy to judge. For example, the questionnaire data indicated that for day recoveries on large deck ships, line-up was the most difficult parameter to judge and power the second most difficult. With regard to day and night recoveries on small deck ships, however, power became the most difficult parameter to judge relative to discerning changes in approach performance.

Although glide slope was rated the most important parameter for a good recovery, it should be recognized that the LSO's judgment of power setting is vital in predicting changes in glide slope performance. Borden in another report (3) stated, "Power and pitch attitude are probably the most important parameters for controlling aircraft approaches because of their direct relationship to glide slope performance."

The concept of an LSO head-up display (HUD) suggested by Borden (3) is now operational on several carriers (4). Although the only added information in the new display is "sink-rate," presentation of all information has been greatly improved. A parameter such as power can still be determined only from the aircraft itself. Thus, the LSO still must hear the aircraft. How much he needs to hear the aircraft, and to what extent such systems as HUD, approach power compensation (APC), and automatic carrier landing system (ACLS) influence the auditory requirements, are unknown quantities. With more extensive use of ACLS, it is uncertain what degree of dependence will be placed on auditory cues. In ACLS minimums the LSO may not be able to see the aircraft before the decision wave-off point is reached (3). If the day/night trend mentioned previously is an indication, then one might predict a decrease in the use of auditory cues. Ambient noise at the LSO work station has, of course, remained unchanged. The probability that significant auditory hazard exists, therefore, is great.

OBJECTIVES

The objectives of the present investigation were as follows:

1. Specify typical LSO noise exposure profiles and relate them to auditory hazard.

2. Determine to what extent auditory cues are employed by the LSO in waving aircraft.

3. Determine and compare average hearing levels for a sample LSO population and an equivalent number of non-LSO pilots.

PROCEDURE

NOISE EXPOSURE

Noise exposure investigations were conducted during carrier qualifications* on board the USS Lexington (AVT-16) and the USS Forrestal (CVA-59). The determination of LSO noise exposure was approached by using two methods. The first approach involved obtaining tape recordings during operations at the LSO platform. A General Radio cassette data recorder (Model 1935) and a precision sound level meter and analyzer (Model 1933) were used for this purpose. Upon return to the laboratory, the tapes were analyzed using Bruel and Kajer equipment. The average peak sound pressure level (Lp), sound level (dBA), and the average duration per aircraft event when the sound level was 90 dBA or greater were derived from analysis of the tapes. An aircraft event was defined as a trap, bolter, wave-off, touch-and-go, or deck launch. By considering both the average sound level and duration of exposure, projections were made of daily noise exposures and these were, in turn, related to current damage risk criteria.

A second approach which utilized personal noise dosimetry was unsuccessful on the USS Forrestal due to interference from a large radar unit. The interference occurred despite the fact that the dosimeter was wrapped with lead tape to reduce EMR entry. The radar interference also precluded the use of the Cosmocord Eardefender unit since a very loud buzz occurred each time the radar antenna rotated. Dosimetry was successful, however, on the USS Lexington where two General Radio noise exposure monitors (Type 9707) were used simultaneously on the subject. The miniature ceramic microphone of one dosimeter was positioned underneath the Cosmocord "active" hearing protector, and the microphone of the other dosimeter was mounted outside the earmuff. In this way, comparative dosimeter readings could be taken to assess the adequacy of the Cosmocord muff and, at the same time, establish the noise exposure of the LSO who does not routinely wear any hearing protective device. The dosimeters also indicated, by a light emitting diode, whether or not a level of 115 dBA had been exceeded during their "on" periods. The dosimeters were removed at the end of a fixed period, usually one hour, and readings were obtained from the associated General Radio noise exposure indicator (Type 1944).

AUDITORY CUES

In an effort to determine the importance of auditory cues to the LSO in waving aircraft, an LSO auditory cue questionnaire was employed (see Appendix A). Senior LSOs at 37 activities were asked to distribute the questionnaire first to active and then to inactive LSOs (no trainees) within their organizations. Since it was impossible to accurately determine the number of LSOs who would receive the questionnaires, fixed numbers of questionnaires thought sufficient to meet the need were sent to each major activity: 15 to each TRAWING, 20 to each CAG, 6 to each Force LSO, 16 to each Reserve Air Wing, and 6 to each of the RAGs. A total of 470

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*Data were not obtained during cyclic air operations.

questionnaires were mailed out and of these, 225 were returned completed and 70 were returned blank.

The primary purpose of the questionnaire was to have the LSOs comment upon and rate the importance of auditory cues for waving aircraft. Ratings were obtained for day/night conditions in general, and specifically for each aircraft the LSO was qualified to wave. Information was also obtained on the type (if any) of hearing protection worn by the LSOs.

HEARING STATUS

Of the 225 LSOs responding to the auditory cue questionnaire, 150 were re-contacted and asked to participate in the hearing testing aspect of the study. Each LSO was requested to locate a non-LSO pilot of similar age, having the same number of jet and prop flight hours as he, and to have hearing tests conducted on himself and his chosen counterpart at a naval hospital or NRMC branch clinic. Once hearing threshold level data were obtained on both individuals, the data form was to be completed and returned to Pensacola for comparative analysis. It was reasoned that if the non-LSO pilot and LSO were matched for flight hours and age, then any difference in hearing could be attributed primarily to the LSO's duties. The letter sent to the LSOs and the data sheet for this phase of the study are shown in Appendices B and C, respectively. A separate letter was sent to branch clinics in the various medical regions requesting that the hearing tests be conducted only by qualified audiometric technicians or AVTs, utilizing manual rather than self-recording audiometers. Air-conduction thresholds were to be obtained at 0.5, 1, 2, 3, 4, 6, and 8 kHz bilaterally.

Unfortunately, of the 150 LSOs contacted, only 25 returned hearing data for themselves and their non-LSO counterparts. Initially, the LSOs had been contacted personally by the investigator, and this contact was ultimately followed by formal letters through COMNAVAIRLANT, COMNAVAIRPAC, and CNATRA from CO, NAMRL.

RESULTS AND DISCUSSION

NOISE EXPOSURE

Table I summarizes the noise dosimetry data obtained during four noise measurement periods (labeled A through E) on the USS Lexington. In all but one instance (measurement period A, A6 aircraft), two dosimeter values are shown for each measurement period. The condition identified as "active protector" refers to the dosimeter readings obtained when the dosimeter's miniature microphone was under the Cosmocord Eardefender. The "open" condition refers to that time period when the microphone of the sound dosimeter was placed near the ear, but was open to the noise environment. Note that in every case when the active protector was worn, 115 dBA was never exceeded at the ear and no dosimeter value exceeded 40 percent of the 8-hour projected noise exposure. For example, in measurement period B, which lasted one hour, the subject was exposued to forty-six A7 events (trap, bolter, wave-off, and touch-and-go), producing a dosimeter reading of five. Projecting to an 8-hour exposure (8x5) the dosimeter reading would be only 40 percent. In the open ear condition, damage risk criteria (DRC) were exceeded in all cases because 115 dBA was exceeded. Damage risk criteria would also be exceeded in all but one case (analysis period C) because the projected 8-hour exposure would exceed 100 percent. In measurement period C, the projected 8-hour exposure would be approximately 85 percent.

Table I

LSO Noise Dosimeter Data (USS Lexington)

Noise Measurement Period	Duration	A/C	Number of Events	Dosimeter Reading: Reading for Open Ear Condition >115 dBA*	Dosimeter Reading: Reading for Active Protector Condition >115 dBA*
A	1 hr	A6	32	37 / Yes	---
B	1 hr	A7	46	34 / Yes	05 / No
C	45 min	T2	21	08 / Yes	01 / No
D	1 hr	TA4	45	22 / Yes	05 / No
E	1 hr	A7	31	20 / Yes	03 / No

*Indication as to whether 115 dBA was exceeded

It should be noted at this point that current DRC are established on an 8-hour, 90 dBA standard. In a CARQUAL situation operations routinely last 10 hours, and it is not uncommon for 12-14 hour operational periods to occur. Also, the Navy DRC are soon to be changed to the much more conservative 8-hour 85 dBA standard. It is not unusual for an LSO to spend close to 8 hours on the platform in any 24-hour period. Furthermore, LSOs are often on the platform observing, even when the aircraft being worked is of a type different from that which the LSOs are assigned to wave. It is clear from the foregoing that dosimetry data alone strongly support LSO over-exposure to noise. The data also point out that the use of an active hearing protective device can prevent over-exposure. The adequacy of such a device for supplying sufficient auditory cues to the LSO may be worthy of further investigation.

Data on average noise levels and average time per event for various aircraft measured at the LSO platform are shown in Table II. The number of seconds per event that the noise level was above 85 or 90 dBA is shown for both traps and wave-offs. Note that, on the average, wave-offs produced significantly higher noise levels that were of longer duration than levels produced by traps for the same aircraft. The difference between the linear (dB-SPL) and dBA measurements is an indicator of the spectrum of the noise—the larger the difference, the more low frequency energy is present. As shown in Table II, these differences range up to 9 dB for the A7 traps, indicating that a good deal of low frequency energy is present. For the same type of aircraft on wave-off, the difference is only 1 dB, indicating a substantial change in the noise spectrum of the aircraft, compared to the trap. It is known that hearing protective devices are much less efficient in the presence of low frequency energy. This would have to be taken into consideration in the design of an LSO hearing protective device since the greatest number of events to which an LSO is exposed are traps. The data also indicate that, of the aircraft for which noise measurements were obtained, the TA4 has the highest level and also the longest average trap time over 90 dBA. It should be noted that ambient noise on deck has not been considered thus far. Ambient noise would create a continuous background level of about 100 dBA during CARQUALS. The aircraft events would superimpose the noise levels just discussed on the ambient noise, producing a still greater noise hazard. Even the LSO's time away from the platform does not afford him a satisfactory auditory recovery environment since squadron ready rooms and billeting areas are close to catapult machinery room spaces and are subject to high noise levels during launches.

Table II

Average Noise Levels Measured at LSO Platform (USS Lexington)

	A/C	Average Noise Level dB(SPL)	dBA	Average Time Per Event (seconds)>85 or 90 dBA
Traps				
	T2	111	107	8.4(>85)
	TA4	121	113	9.5(>90)
	A6	116	109	8.3(>90)
	A7	114	105	7.3(>90)
Wave-Offs				
	T2	120	119	13(>85)
	TA4	---	120	7(>90)
	A6	121	118	13(>90)
	A7	128	127	11(>90)

Table III presents typical data on average noise levels and average time per event for various aircraft measured at the LSO platform on a "large deck" carrier (CVA-59). Two sampling time periods are described: Run "A" was one hour in duration and Run "B" was 1½ hours in duration. Run "A" was primarily an F4 evolution with a total of 64 events and Run "B" an EA6B evolution with a total of 54 events. As can be seen, the overall peak dBA levels are in the range of 116-134 dB for both aircraft types. The projected 8-hour exposure for Run "A" would be 47 minutes at >90 dBA and for Run "B", 35 minutes at >90 dBA. These exposures, coupled with an approximate 100 dBA ambient noise during operations, again indicate the hazardous nature of the LSO's duties in relation to hearing.

Table III

Typical Noise Levels Measured at LSO Platform (USS Forrestal)

Run "A" Duration 1 Hour

	A/C	Number of Events	Average Noise Level dB(SPL)	dBA	Average Duration Per Event 90 dBA or over (sec)
Traps	F4	35	128	122	5.4
	A7	1	123	114	4.0
	C1	2	114	108	5.0
Bolter	F4	6	120	116	4.6
Wave-Off	F4	8	125	124	5.2
Touch & Go	F4	10	129	121	4.3
Deck Launch	C1	2	127	123	20.0
		Run "B"	Duration 1.5 Hours		
Traps	EA6B	26	127	123	5.6
	A3	7	125	124	7.4
	C1	1	115	102	8.0
Bolter	A3	2	123	123	13.5
Wave-Off	EA6B	7	135	134	8.2
	A3	1	129	129	11.0
Touch & Go	EA6B	8	131	126	5.9
Deck Launch	C1	2	126	124	20.0

AUDITORY CUES

The results of the auditory cue questionnaire are shown in Table IV and are based on responses from 225 LSOs. Identifying information is covered in questions one through three. Responses to question four indicate that the majority of LSOs (80%) do not wear hearing protection devices while waving aircraft. Of the 20 percent who do, 32 of 44 LSOs wear earplugs in both ears, the most widely used type being the standard issue V-51R single flange. The second most popular earplug was the EAR, an extremely comfortable cylindrically shaped compressable plug of polymer composition. Four LSOs reported using the custom molded NOISEBREAKER. Of those wearing a single plug, most indicated protection for the other ear was provided by the telephone-type handset used to communicate with the pilot of the aircraft on closest approach. With 80 percent of the sample population wearing no protection in such a hazardous noise environment, a high priority effort should be made to provide a more widely acceptable type of hearing protection for these personnel.

Judging from the responses to question five, it is obvious that LSOs feel that they need to hear approaching aircraft in order to do a good job. Only one percent of the sample population responded negatively to this question. Auditory cues were rated more important at night than during the day. This finding appears more logical than the opposite finding in the earlier study by Borden (2).

The prospect of wearing a protective device that would reduce but not eliminate auditory cues (question six) met with almost an equal number of yes and no responses. This is a sufficient negative response to predict that a device that partially limited auditory cues would not meet with overall success within the LSO community.

The idea of wearing a device that would permit passage of critical auditory cues and at the same time act as a hearing protection device was well received — 92 percent of the respondents answered question seven positively. There is such a device in current production — the British EARDEFENDER, mentioned earlier. Although this particular unit would not have off-the-shelf application for the LSO, its basic concept certainly appears valid for the LSO environment. It is apparent from the responses to question eight that the majority of LSOs would prefer not to wear a device with a cable attached, even one with a quick disconnect feature.

An active hearing protective device designed to be used in conjunction with a redesigned UHF telephone handset could be developed. Modification of the handset could include addition of a high-performance noise-cancelling microphone and an earpiece that would produce good acoustic coupling to the hearing protective device. Close acoustic coupling to the protective device would be necessary to exclude as much ambient noise as possible. The use of a noise-cancelling mike would provide a much more intelligible speech signal to the pilot of the aircraft on final approach.

Table IV

LSO Auditory Cue Questionnaire
(N=225)

1. Percentages of respondents by location:

Location		Average Yrs LSO	Qualification	
AIRLANT	34%	4.5	Squadron	38%
AIRPAC	55%	5.0	Wing	34%
TRACOM	11%	5.0	Staff	28%

2. Day/night qualified 84%
   Day only 16%

3. Currently waving 72%

4. A. No hearing protection 80% (181)
   B. Hearing protection while waving 20% (44)

a. One ear:

	Percent	Number
EAR	2	1
V-51R	25	11
	27	

b. Both ears:

	Percent	Number
EAR	23	10
Noisebreaker	9	4
Wax Impr Cotten	2	1
V-51R	39	17
	73	

5. Need to hear aircraft to do a good job:
   - Yes 83%
   - Depends on aircraft 16%
   - No 1%

6. Would you wear a hearing protective device that would reduce but not eliminate auditory cues?
   - Yes 46%
   - No 54%

7. Wear device but hear same aircraft sound and also protect hearing?
   - Yes 92%
   - No 8%

8. Would you wear earmuff with cable (UHF)?
   - Yes 31% (44% with quick disconnect)
   - No 69%

   If no, would you wear with quick disconnect?
   - Yes 19%
   - No 81%

9. In what aircraft are you carrier qualified? (Not tabulated)

10. Types of aircraft and average degree of importance of auditory cues (5=most important):

Aircraft	Average Auditory Cue Importance	Number of Respondents
A3	4.7	143
F8	4.1	79
A5	3.9	72
F4	3.8	174
S3	3.8	50
A7	3.7	188
F14	3.7	44
EA6B	3.7	59
RA5C	3.7	43
TA4	3.6	13
A4	3.0	11
A6	3.5	187
T2	3.0	11
A1	2.6	12
E1	2.5	44
S2	2.4	49
C1	2.4	155
E2	2.3	167
C2	2.2	125

11. When the following conditions are present, are you more (value 3), equally (value 2), or less (value 1) dependent on auditory cues to wave?

Condition	Average Value	Number of Respondents
Night	2.9	218
Poor Visibility	2.8	218
Novice Pilot	2.6	218
High Sea State	2.6	217
APC	2.0	218
ACLS	1.9	201

12. Average period of time aircraft can be heard prior to decision wave-off point = 7.9 sec. n=210

13. If you can't hear incoming aircraft due to other noise on deck, is safety of recovery compromised?

Yes	78%
No	22%

14. Are you aware of aircraft accident because LSO couldn't hear approaching aircraft?

No	94%

Responses to question ten point out that it is more critical to have auditory cues for aircraft having engines with longer "spool-up" times or high inertia (e.g., A-3). Propeller type aircraft received consistently lower ratings than jets on the auditory cue parameter.

Any factor that causes a deviation from optimal day conditions increases the importance of auditory cues (e.g., poor visibility). In response to question eleven, all but the approach power compensator (APC) and automatic carrier landing system (ACLS) conditions received high ratings (3.0=more dependence on auditory cues).

Seventy-eight percent of those surveyed said that the safety of the recovery would be compromised if they could not hear the approaching aircraft because of other noise on deck (question thirteen). Many respondents pointed out the likelihood of more excessive noise on deck during carrier qualifications than during cyclic operations. Although not asked on the questionnaire, many indicated they felt that the noise exposure during field carrier landing practice (FCLP) was greater than that which occurs on the ship. Appendix D catalogs responses to question thirteen from 43 LSOs who said they currently wear hearing protection. Eighty-eight percent of the group responded positively to this question, with some individuals mentioning difficulty in UHF communication as an added factor impacting on safety (difficulty by the LSOs and the pilots in hearing each other). Responses from this sub-group are felt to be of interest because they were operating on reduced auditory cues while routinely wearing hearing protection. Also pointed out in the responses was that vision is the primary input mode with audition secondary. However, the authors feel that audition may be the only predictive cue the LSO has when "smoke" cannot be used to judge power settings. Thus, under certain conditions, e.g., night, pitching deck, and nugget pilot, auditory cues may become primary. In general, however, consensus from the LSOs seems to be, "We'll take all the sensory cues that we can get."

Regarding question fourteen, there were few reports of accidents when aircraft were not heard by the LSO, but many LSOs stated that there were frequent occasions when an accident was prevented because the LSO did hear a power change. Affirmative responses to question 14 are tabulated in Appendix E. It was also pointed out that the LSO must hear the back-up LSO and the two LSO talkers. Most often, communication is conducted during periods of high noise, but it also occasionally occurs during relatively quiet periods. This is another reason that the development of an active protector appears to be the most logical direction in which to proceed.

LSO HEARING STATUS

As mentioned previously, hearing threshold level (HTL) data were obtained from 25 LSOs and 25 pilots with no LSO duties in their job history. These data are presented in Figure 1.

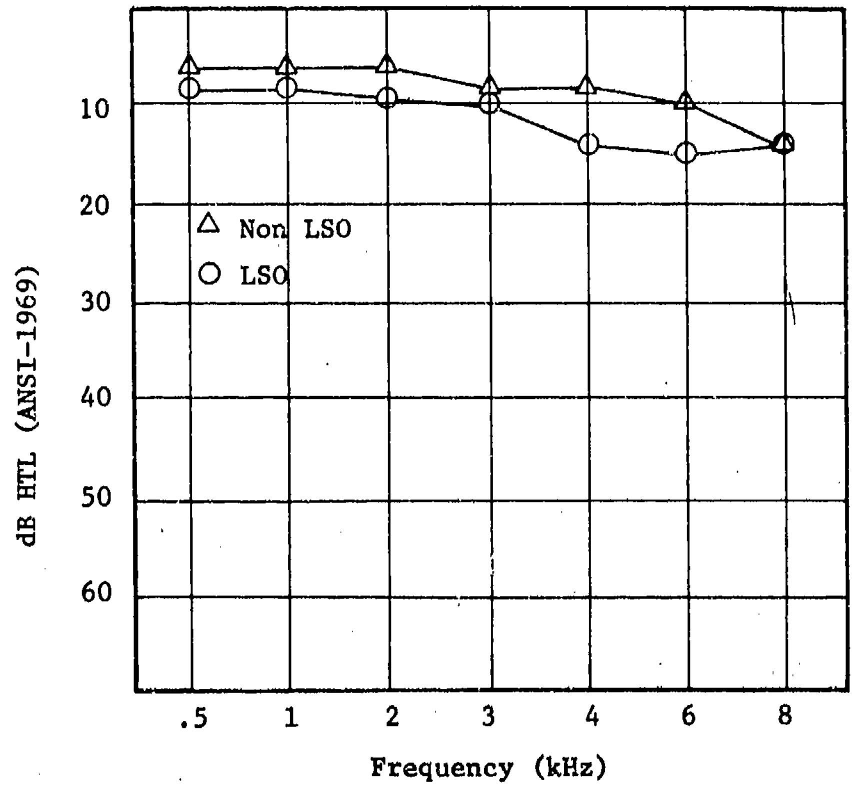

Figure 1

Average hearing threshold levels (HTLs) obtained from 25 LSOs and 25 non-LSOs (left and right ears combined).

As can be seen, the LSOs displayed poorer hearing at 4 and 6 kHz (6 dB and 5 dB, respectively) than their non-LSO counterparts. This trend suggests the need for a further larger scale investigation of the hearing status of these two groups. However, as was indicated earlier, implementation of such a study may prove to be difficult. Since self-recording audiometric test results found in medical records are not felt to be sufficiently reliable for this application, manual audiometers should be utilized to obtain HTL data at the time of the LSO's annual physical.

The differences shown in Figure 1 for 4000 and 6000 Hz are considered significant clinically. However, they are not so large as one might expect, based upon the noise levels and noise exposures documented previously in this paper and their relationship to current damage risk criteria. It might be theorized that LSOs are individuals who are particularly resistant to noise-induced hearing loss. Perhaps some individuals who enter the LSO pipeline soon find the noise to be very annoying, or maybe they experience adverse auditory symptoms from the noise and drop out, thereby leaving the more noise resistant individuals to continue. Since susceptibility to noise-induced hearing loss is an extremely variable characteristic, it would be interesting to contact individuals who dropped out early in training to determine the validity of this hypothesis.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn from the investigation:

a. The LSO is exposed to hazardous noise levels in the execution of his duties during carrier operations. The wearing of hearing protective devices is presently the only reasonable way to control the LSO's noise exposure.

b. For optimal safety and management of carrier landings under all acoustical conditions, it is necessary for the LSO to have full access to aircraft auditory cues. It is recommended that an "active" type hearing protective device be developed for the LSO. In conjunction with such a development should be a redesign of the UHF handset. Particular emphasis should be placed on the use of a superior noise-cancelling microphone and an earpiece designed to give good noise rejection when combined with the new protector. These should be collateral projects so that the protective device and the handset can act as a unit.

c. There is a trend for LSOs to have poorer hearing than non-LSO pilots when matched for age and number of flight hours. Further hearing threshold level studies should be undertaken, on a larger scale, using the same requirements as in the present investigation.

d. An investigation should be undertaken to determine the hearing characteristics and attitudes toward noise (e.g., annoyance) of those LSO candidates who drop out during training. Such data could be used to test the hypothesis that primarily those personnel who are resistant to noise-induced hearing loss continue as LSOs.

e. Noise level and noise exposure data of the types presented herein should also be obtained during cyclic air operations.

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APPENDIX A

February 1977

From: Acoustical Sciences Division, Naval Aerospace Medical Research Laboratory, Naval Air Station, Pensacola, Florida 32508
To: Landing Signal Officers

Subj: NAMRL LSO Auditory Cue Questionnaire

1. This division has been tasked by BUMED to conduct a study within the LSO community. The study has the following objectives:

a. Specifying typical LSO noise exposure profiles and relating them to auditory hazard.

b. Determining the prevalence and characteristics of hearing loss within the LSO population and comparing these findings to a population of non-LSO pilots.

c. Determining to what extent auditory cues are employed by LSOs to judge the appropriateness of certain parameters of pilot/aircraft approach performance.

d. Development of the most efficient and effective hearing protective device for LSOs.

2. This questionnaire is the first step toward the final goal of developing a suitable device for protection of your hearing. The following are guidelines for filling out the questionnaire.

a. Only QUALIFIED LSOs are to respond to the questionnaire. TRAINEE responses are not being elicited at this time.

b. Please take as much time as necessary to carefully respond to the questions.

c. Please answer every question completely.

d. Fill out the questionnaire independently. Do not discuss your responses with other LSOs until you have all completed the questionnaire.

3. If you have any questions, comments or contributions in relation to the questionnaire or the overall project please call Dr. R. M. Robertson at NAMRL, Av 922-4457.

4. Each of the three senior staff LSOs (COMNAVAIRPAC, COMNAVAIRLANT and CNATRA) are familiar with this project in detail, are supportive of it, and encourage your cooperation.

5. I am looking forward to meeting many of you personally during the course of this study (the overall project should extend through FY78). Later on you may be contacted in regard to having your hearing tested. I would again solicit your utmost cooperation in that phase of the study.

6. When you have completed the questionnaire, fold it twice and tape it together. The stamped side with our return address should be visible. Mail back as soon as possible after you complete it. Please make sure you have signed the Privacy Act Statement.

R M Robertson

R. M. ROBERTSON, Ph.D.

LSO AUDITORY CUE QUESTIONNAIRE

NAME ______________ AGE: ______________ RANK: ______________ DATE ______________

UNIT ______________________________ HOW LONG LSO? __________ SSAN: ______________

1. **LOCATION:**

☐ AIRLANT
☐ AIRPAC
☐ TRACOM

QUALIFICATION:

STAFF ☐
WING ☐
SQUADRON ☐

2. Are you fully day/night qualified?

☐ YES ☐ NO

If NO explain ______________________________
____
____

3. Are you currently waving?

☐ YES ☐ NO

If NO; how long since you have waved? ______________________________

4. What type of hearing protective device do you use while waving? If none; so state ______________
____
____

5. In general, do you feel you need to hear the aircraft you are waving to do a good job?

☐ A. YES ☐ B. Depends on A/C type. ☐ C. NO

If you check A or B, what degree of importance would you assign to auditory cues?
(5 = most important; circle number)

DAY	1	2	3	4	5
NIGHT	1	2	3	4	5

6. Would you wear a hearing protective device that would reduce but not completely eliminate auditory cues?

☐ YES ☐ NO

7. Would you wear a hearing protective device that would permit you to hear about the same A/C sound level but would protect your hearing too?

☐ YES ☐ NO

8. Would you wear an ear muff device with a cable (to permit UHF communication)?

☐ YES ☐ NO

If NO, would you wear it if it had a quick disconnect in the cable?

☐ YES ☐ NO

9. In what aircraft have you carrier qualified?

______________ ______________ ______________
______________ ______________ ______________
______________ ______________ ______________

10. For what type of aircraft are you a qualified LSO and what degree of importance do you consider auditory cues to be relative to each aircraft type? (5 = most important; circle number).

Aircraft	Auditory Cue Importance
______	1 2 3 4 5
______	1 2 3 4 5
______	1 2 3 4 5
______	1 2 3 4 5
______	1 2 3 4 5
______	1 2 3 4 5
______	1 2 3 4 5
______	1 2 3 4 5
______	1 2 3 4 5
______	1 2 3 4 5

11. In general, when the following conditions are present, are you more, equally or less dependent on auditory cues to wave?

	M	=	L		M	=	L
ACLS	☐	☐	☐	High sea state	☐	☐	☐
APC	☐	☐	☐	Novice pilot	☐	☐	☐
Poor visibility	☐	☐	☐	Night	☐	☐	☐
Other (specify): ______					☐	☐	☐

12. Estimate how long (range in seconds) you can hear an aircraft on final approach before the wave-off point is reached. ______ seconds.

13. If you cannot hear the aircraft on final approach due to other noise on the deck, do you feel the safety of the recovery is compromised?

☐ YES ☐ NO

Why? ______

______

14. Are you aware of an aircraft accident occurring because the LSO could not hear the approaching aircraft?

☐ YES ☐ NO

If YES, give details of the accident, if possible.

______

______

______

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OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

RONALD M. ROBERTSON, Ph.D.
Acoustical Sciences Division
Naval Aerospace Medical Research Laboratory
Building 1953 Code L34A
Naval Air Station
Pensacola, Florida 32508

PRIVACY ACT STATEMENT

Under the authority of 5 USC 301, and EO 9397, personal data are requested so that we will be able to identify you if it is necessary to recontact you at a later date for clarification of your responses to the questionnaire. The information provided by you will become part of NAMRL records. The information provided will not be divulged without your written authorization to anyone other than data processing, professional and technical personnel within NAMRL. You are not required to provide this information; however, failure to do so could result in your questionnaire responses being deleted from the survey if we could not reach you for necessary clarification of a response.

SIGNED: ______________________

(FOLD IN FIRST)

APPENDIX B

NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY

PENSACOLA, FLORIDA 32512

IN REPLY REFER TO:

May 1977

From: Acoustical Sciences Division, Naval Aerospace Medical Research Laboratory, Naval Air Station, Pensacola, Florida 32508

To:

Subj: LSO and Non-LSO Hearing Test Data; request for

Ref: (a) NAMRL LSO Auditory Cue Questionnaire February 1977

1. As previously communicated to you in reference (a), the Acoustical Sciences Division, NAMRL, has been tasked by BUMED to conduct a research study within the LSO community. The objectives of the study are as follows:

a. Specify typical LSO noise exposure profiles and relate them to auditory hazard.

b. Determine the prevalence of hearing loss within the LSO population and compare these findings to a population of non-LSO pilots.

c. Determine to what extent auditory cues are employed by the LSO in waving aircraft.

d. Develop an efficient and effective means of hearing protection for the LSO.

2. Your cooperation in completing the NAMRL LSO Auditory Cue Questionnaire is greatly appreciated. Results from 216 returned questionnaires are currently being analyzed.

3. Your cooperation is again requested in the hearing test phase of the study. Would you please do the following:

a. Locate a pilot having approximately the same number of jet and prop hours as you have and who is approximately the same age ($\pm$ 2 yrs), but who has no history of LSO duties.

b. Arrange to have hearing tests done on both of you at your branch clinic on a manual audiometer. If at all possible, go together so that the tests will be done on the same equipment by the same trained technician.

c. Make every effort to have been out of high level noise for several hours before taking your hearing test.

d. When the hearing test data portion of the enclosed form has been completely filled out by the technician, please fold the form twice and fasten. Be sure the stamped side with the NAMRL return address is visible. Mail the data back as soon as possible after you and your non-LSO counterpart have been tested.

e. Please be sure you have both signed the consent/privacy act statement.

4. The imposition on your time is recognized. Let me thank you in advance for your efforts in complying with this request.

5. If you have any suggestions, questions or comments regarding any aspect of the study or cannot comply with the request, please call me at NAMRL, AV 922-4457.

R. M. ROBERTSON

APPENDIX C

LSO SUBJECT	NON-LSO SUBJECT
Date: ____ Location: ____	Date: ____ Location: ____
Audiometer Calibration Date: ____	Audiometer Calibration Date: ____
Examiner's Name/Rate: ____	Examiner's Name/Rate: ____
Subject's Name: ____ Age: ____	Subject's Name: ____ Age: ____
Unit: ____ LSO for ____ Yrs.	Unit: ____
Prop Hrs: ____ Jet Hrs: ____	Prop Hrs: ____ Jet Hrs: ____

MANUAL TEST RESULTS

	500	1000	2000	3000	4000	6000	8000		500	1000	2000	3000	4000	6000	8000
Right Ear								Right Ear							
Left Ear								Left Ear							

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NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FLORIDA 32508

SUBJECT CONSENT FORM
FOR PARTICIPATION IN NON-HAZARDOUS INVESTIGATIONS

NAMRL LSO AND CONTROL GROUP HEARING SURVEY

1. I, (1) ______________________, (2) ______________________ hereby consent to participate as a subject in the research study being conducted by the Acoustical Sciences Division of NAMRL. I understand that the adequacy of safety measures has been certified by the Safety Committee of NAMRL and that the Committee for the Protection of Human Subjects of NAMRL has determined that the procedures to be employed in this study are not hazardous in any way to humans.

2. The nature and purpose of the procedures have been fully explained to me by the person responsible for direction of this study.

3. In making my decision to participate in this study, I am not relying upon any information or representation not set forth in this document, or in the discussion of the nature of the study with the investigator. My consent is given as an exercise of free will, without any force or duress of any kind. I understand that my consent to participate in the above research project may be revoked at any time, and that such revocation of consent may be done without prejudice to myself. I understand that my consent to participate does not constitute release from any possible future liability by the United States attributable to the procedures employed in the investigation.

PRIVACY ACT STATEMENT

Under the authority of 5 USC 301, personal data are requested in order that we might identify you if it is necessary to re-contact you at a later time. The information provided by you will become part of NAMRL medical records. The information provided will not be divulged without your written authorization to anyone other than data processing personnel and professional and technical personnel within NAMRL. You are not required to provide this information; however, failure to do so would result in our inability to reach you for additional information and/or to inform you of any unusual findings that would be of personal interest to you. Also, data collected for the study could be unusable if it was not possible to retrieve your particular findings.

Signed: (1) ______________________ Witnessed: ______________________
(Audiometric Technician)

(2) ______________________ Date: ______________________

APPENDIX D

Responses to Question 13 on LSO Auditory Cue Questionnaire
from LSOs Who Wear Hearing Protection
N=43 LSOs

Question 13: If you cannot hear the aircraft on final approach due to other noise on the deck, do you feel the safety of the recovery is compromised?

- "Other than having one less indication of power setting, pilot response, etc., excess noise on deck is fatiguing and distracting (i.e., in close foul decks)."

- "Usually can't communicate via UHF in addition to audio cues."

- "I don't catch an underpower situation as quickly."

- "Just slightly, as it's a clue I've learned to use, but can easily adapt to surrounding conditions."

- "Overall ability to wave aircraft will depend on hearing the aircraft engines, depending upon aircraft type. The safety of a recovery is <u>somewhat</u> compromised when certain types of aircraft cannot be heard."

- "I am a little more nervous because I can't tell where the pilot has his power."

- "Diminishes most auditory cues besides hampering UHF transmissions - distracting."

- "Usually LSO's ability to talk is also compromised by noise through radios. Also, ability to hear the aircraft power changes."

- "The other noise is distracting; in the case of A3 or F14 the LSO's ability to discern cuts is impaired."

- "At night large reductions in power are not readily apparent."

- "Have had numerous pilots reduce power excessively in - close."

- "Depending on aircraft, I need to hear engine responses to glideslope/speed errors."

- "Because if I'm talking to the pilot, or he's talking to me, the noise is distracting. It is still as safe as it can be, however."

- "It is important to get the full picture of the aircraft, attitude, power and airspeed for a safe approach."

- "Because you can tell the pilot what his aircraft is going to do before it actually does it when you hear power corrections."

- "With an A7 or F8 I want to be able to tell where the power is."

- "It takes away any auditory cues that exist."

- "Loss of cue for power setting."

- "Not only because I can't hear aircraft on final but more from the distraction. Particularly if the aircraft are being moved (jet blast, foul deck, etc.)."

- "Noise interferes with required platform communications. UHF communications, and aircraft auditory cues."

- "Not so much in the daytime but at night in order to anticipate how the pilot is reacting to corrections since you can only see his approach lights; not the whole aircraft."

- "Not so much during the day, but I feel it is considerably compromised at night."

- "Can't hear clara calls if aircraft turning behind you or power on touchdown."

- "At night especially, the aircraft sound is the only indication of power setting which tells the LSO which way the aircraft is going to go (decel, accel, hi low, etc.)."

- "A3s in particular, you can hear the power come off before the aircraft starts to decel."

- "LSO distraction, background noise in close LSO inability to hear aircraft power changes."

- "Generally impaires LSO overall state of awareness. F14 turning on deck nearby virtually deadens most other sensory perception, including vision; it hurts."

- "I feel my concentration is not fully devoted to the aircraft on final."

- "Engine noise and associated . . . with power additions/reductions give instant indication of aircraft power conditions."

- "To some degree, if the approach is well within safe parameters no problem; however, any problems with the approach, then more distraction hurts the waving."

- "Auditory cues may be your only hint of trouble prior to a significant glide slope deviation."

- "Less available cues to wave by."

- "To a certain extent."

- "Cannot hear airplane in groove, might miss radio transmissions."

- "Reacting to audio cues reduces LSO response time."

- "Depending on aircraft, hearing aircraft noise is needed."

- "Communications between LSO, prifly, etc., becomes hard; continual noise causes irritation and loss of concentration after prolonged exposure."

- "High noise levels inhibit communication plus deny the LSO auditory cues of aircraft power changes."

- "No, hearing the aircraft is an important part but is never considered more than airspeed glideslope, position, etc."

- "No, the only time this would become a factor is night and pitching deck where some of the eyeball cues are absent."

- "No, noise on deck has never been loud enough to drown out the aircraft noise."

- "No, noise of approaching aircraft is not a primary sensory signal for the LSO, however, it can help the LSO especially at night and in low visibility conditions."

- "No, I can still judge the aircraft performance by looking at its AOA and overall relationship to glide slope, hearing the power is just a helpful hint as to what the aircraft may eventually do."

APPENDIX E

Remarks Following "Yes" Responses to Question 14 on LSO Auditory Cue Questionnaire

Question 14: Are you aware of an aircraft accident occurring because the LSO could not hear the approaching aircraft?

- "Ramp strike during night carrier quals, LCDR pilot experienced aircraft were launching, extreme noise (27C ship) pilot reduced power in close on a night pitching deck, aircraft A strike, pilot OK."

- "I have seen hard landings and blown tires because the LSO could not hear the power come on. Attitude was added but power was not added; the LSO thought the power came on with the attitude but was not able to hear it."

- "CQ-RAG-Night; aircraft turning on cat with aircraft in the groove decelerating. I have seen two ramp strikes in this situation where the LSO may have detected the decel early enough to give corrective calls or wave-off, if he had been able to hear the engine of the approaching aircraft."

- "Sea stories from big deck LSOs; almost always due to turning aircraft behind platforms."

- "Aircraft turning up on elevator behind LSO platform, aircraft on approach appeared to settle all of a sudden; LSO could not hear obvious power reduction until too late; aircraft hit ramp; AAR board determined above as major contributing factor (F-8)."

- "Aircraft landed with LSO's back to aircraft; he was wearing earmuffs."

- "I believe that several ramp strikes could have been averted had the LSO paid more attention to engine RPM."

- "Contributing cause: (1) night A-7, initial CQ, standby aircraft (A-7) turning at idle abeam island, (2) night A07, CQ, standby F-4 turning at idel on #4 elevator."

- "Contributed to two F-8 ramp strikes on Oriskany, LSO unable to ascertain power setting."

- "A-7, night, high in close power back to correct for high. LSO did not hear or failed to note power setting until high rate of descent was set up. Because of spool time, power calls, wave-off, and throttle at military setting were not enough to prevent tail from striking the ramp. Bolter occurred, oil lines failed, engine seized, and the aircraft was lost."

- "Not an accident, but feel that this was a contributing factor to a hook slap by an F-14 on USS Ranger. F-14 turning on deck, couldn't hear power on aircraft; black night, nugget carqual, went for it."

- "At night, large power reduction in close; aircraft settled and hook hit round down. Have seen other similar to this, aircraft landed well short of #1 wire."

- "(1) F-3 landed on COD on fantail; aircraft in vicinity turning;
  (2) F-8 hit ramp EGTL - F-8 turning on shelf aft of island;
  (3) (contributory) A-3 hit ramp night, high wind condition and too many people on platform training."

- "Ramp strike; aircraft turning on deck during carquals LSO did not notice large reduction of power in close resulting in no wave-off and ramp strike; pilot lost (A-7)."

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NAMRL - 1255
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8. CONTRACT OR GRANT NUMBER(s):
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18. SUPPLEMENTARY NOTES: Mr. Maxwell, at the time of this investigation, was with the Hearing Conservation Service, Naval Aerospace Medical Institute. He is currently with the Hearing Conservation Branch, Navy Environmental Health Center (Pensacola).
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aircraft noise
Hearing
Hearing Conservation
Hearing Standards
Auditory Cue Detection
Human Subjects

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Landing signal officers (LSOs), exposed to high noise levels in the execution of their duties during carrier qualifications, do not routinely wear any hearing protective device. Noise measurements and noise exposure data are needed in order to determine whether such exposures can, over time, produce significant noise-induced hearing loss.

Noise measurement data and noise exposure data obtained during carrier

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) qualifications on board the USS Lexington (AVT-16) and the USS Forrestal (CVA-59) confirm a potential damage risk to hearing. The wearing of hearing protective devices is presently the only reasonable way to control the LSO's exposure to noise.

Questionnaire data from 225 LSOs indicate that for optimal safety and management of carrier landings under all acoustical conditions, it is necessary for the LSO to have full access to aircraft auditory cues, not attainable with currently available off-the-shelf hearing protective devices.

A comparison of average hearing threshold levels for LSOs and non-LSO pilots, matched for age and number of flight hours, indicates a trend for poorer hearing thresholds by the LSOs.

It is recommended that an active type hearing protective device be developed for the LSO, one which would permit passage of critical auditory cues and, at the same time, provide adequate hearing protection. In conjunction with such a development should be a redesign of the UHF handset. Particular emphasis should be placed on the use of a superior noise-cancelling microphone and an earpiece designed to give good noise rejection when combined with the new protector.

It is also recommended that further hearing threshold level studies of LSOs and non-LSO pilots be undertaken on a larger scale.