Ministry of Defence

Air Command Secretariat
Spitfire Block
Headquarters Air Command
Royal Air Force
High Wycombe
Buckinghamshire
HP14 4UE

Ref: FOI2016/10331

[redacted]

28 November 2016

Dear [redacted]

Thank you for your Letter of 1 November requesting the following information:

"I wish to make a Freedom of Information request, relating to research carried out by the Ministry of Defence on noise levels on RAF aircraft flight decks.

During the period 2006 to 2011, the Royal Air Force Centre for Aviation Medicine carried out a research project to measure the 'at ear' and ambient noise levels for various RAF aircraft. This project included making specific measurements of noise levels on TriStar platform.

I request the following information from that research project:

a. *Please supply a copy of the final report into flight deck noise levels on RAF aircraft, as produced by the Royal Air Force Centre for Aviation Medicine.*

b. *If unable to provide the full report, please provide a full extract of the research results for the Puma, Chinook and TriStar platforms from the report described above.*

c. *If unable to provide the full extract, please provide details of the ambient and 'at-ear' noise levels for the Puma, Chinook and TriStar platforms. Also, please provide details of the service issued noise protection provided to Aircrew as part of their Aircrew Equipment Assemblies."*

I am treating your correspondence as a request for information under the Freedom of Information Act 2000 (FOIA).

A search for the information has now been completed within the Ministry of Defence, and I can confirm that some information, in scope of your request is held. I am able to provide you with copies of inflight noise assessment reports for the TriStar, Puma HC2 and Chinook aircraft which includes ambient and 'at ear' noise levels and details of the service issued noise protection provided to aircrew. Section 40(2) has been applied to some of the information in order to protect personal information as governed by the Data Protection Act 1988.

I can confirm that there is no final report for flight deck noise levels on RAF aircraft. Individual aircraft reports are produced on behalf of an individual aircraft project team.

If you are not satisfied with this response or you wish to complain about any aspect of the handling of your request, then you should contact us in the first instance at the address above. If informal resolution is not possible and you are still dissatisfied then you may apply for an independent internal review by contacting the Information Rights Compliance team, 1st Floor, MOD Main Building, Whitehall, SW1A 2HB (e-mail CIO-FOI-IR@mod.uk). Please note that any request for an internal review must be made within 40 working days of the date on which the attempt to reach informal resolution has come to an end.

If you remain dissatisfied following an internal review, you may take your complaint to the Information Commissioner under the provisions of Section 50 of the Freedom of Information Act. Please note that the Information Commissioner will not normally investigate your case until the MOD internal review process has been completed. Further details of the role and powers of the Information Commissioner can be found on the Commissioner's website, http://www.ico.org.uk.

Yours sincerely,

Air Command Secretariat

OCCUPATIONAL AND ENVIRONMENTAL MEDICINE WING

NOISE AND VIBRATION DIVISION

Report: OEM/16/06 Dated February 2006

A REPORT ON AN IN-FLIGHT NOISE ASSESSMENT OF RAF ODIHAM CHINOOK AIRCRAFT CREW DURING NORMAL TRAINING SORTIES

Approved for publication

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OCCUPATIONAL AND ENVIRONMENTAL MEDICINE WING
NOISE AND VIBRATION DIVISION

ROYAL AIR FORCE CENTRE OF AVIATION MEDICINE

Report No: OEM/16/06

A REPORT ON AN IN-FLIGHT NOISE ASSESSMENT OF RAF ODIHAM CHINOOK AIRCRAFT CREW DURING NORMAL TRAINING SORTIES

EXECUTIVE SUMMARY

1. The Noise and Vibration Division of the RAF Centre of Aviation Medicine was tasked by CHE1 of the Chinook IPT to assess the Chinook at RAF Odiham. The purpose of the tasking was to establish the noise exposure of personnel inside the aircraft during flight. The noise assessment was carried out for the Chinook crew during training sorties on 19-23 Sep 05.

2. The work was performed under the purview of a tasking instigated by Eng Pol AW and SHEF covering all aircraft types and variants in the RAF Fleet. This task was prompted by the planned implementation into UK legislation of the European Physical Agents (Noise) Directive as the Control of Noise at Work Regulations 2005.

3. The introduction of the new EU Directive on Noise has the potential to limit the operating time for Chinook crews, due to more stringent action values and the introduction of a limit value, unless steps are taken to mitigate the hazards. The Lower Exposure Action Value falls from 85dB(A) in the current regulations to 80dB(A) in the new regulations. The Upper Exposure Action Value falls from 90dB(A) in the current regulations to 85dB(A). The new regulations also introduce a new Exposure Limit Value of $L_{EP,d}$ 87dB(A) which cannot be exceeded.

4. The Chinook aircraft is a heavy-lift support helicopter flown by 18 and 27 Squadrons at RAF Odiham in Hampshire. The Chinook is primarily used for trooping and for load carrying (both internal and underslung) and can carry up to 54 troops or 10 tonnes of freight. The cabin is large enough to accommodate 2 Land Rovers, while the 3 underslung load hooks allow flexibility in the type and number of loads that can be carried. Secondary roles include Search and Rescue and Casualty Evacuation. The crew of 4 consists of either 2 pilots, or a pilot and navigator, and 2 loadmasters. The Chinook is unique in the RAF fleet in that it has 2 main rotors instead of a main rotor and a tail rotor.

5. A worst case aircrew noise exposure level of 94dB(A) was measured during this survey. Daily time limits for exposure based on the forthcoming legislation are: 19 minutes to the Lower Exposure Action Value (80dB(A)), 1 hour to the Upper Exposure Action Value (85dB(A)) and 1 hour and 35 minutes to the Limit Value (87dB(A)). It should be noted that this assumes that the crewmembers spend the rest of the day in a quiet environment. It can, therefore, be assumed these values are the time limit from engine start to engine stop i.e. their total exposure time. Given the normal length of time spent aboard the aircraft, Chinook aircrew are at risk from Noise Induced Hearing Loss (NIHL).

6. The worst case passenger noise exposure level of 101dB(A) was measured during this survey, for a passenger connected to the communications system. Daily time limits for exposure based on the forthcoming legislation are: 3 minutes to the Lower Exposure Action Value (80dB(A)), 12 minutes to the Upper Exposure Action Value (85dB(A)) and 19 minutes to the Limit Value (87dB(A)). It should be noted that this assumes that the passengers spend the rest of the day in quiet environment and can therefore be assumed as the time limit from engine start to engine stop i.e. their total exposure time. Given the normal length of time spent aboard the aircraft, Chinook passengers are at risk from NIHL.

7. Aircrew operating Chinook aircraft should be informed that they are at risk of NIHL and should be given training to minimise the risk and in the correct use of Personal Protective Equipment (PPE). A helmet offering higher levels of attenuation should be procured, possibly with an active noise reduction capability, although this is secondary to high passive attenuation.

8. Noise levels at the ear must be reduced in order to allow the Chinook aircraft to fly sorties of the required length without the crewmembers being exposed to average levels exceeding the action and limit values defined in the legislation. This can be achieved by reducing the ambient cabin noise and increasing the level of hearing protection offered to the crew.

9. Noise levels to which passengers are exposed must be reduced. All passengers, including those wearing the Mark 15 Passenger helmet, should be issued with and use Acaro Classic Foam Earplugs (NSN 6515-99-126-3570).

DISTRIBUTION LIST

External:

Action:

DLO Yeovilton	CHE1, Chinook IPT	[redacted]

Information:

RAF Benson	RWOETU Chinook Navigator	[redacted]
RAF Odiham	Station Commander	
	OC 18 Squadron	
	OC 27 Squadron	
HQ PTC	DGMS(RAF)	

Internal:

Information:

RAF CAM Library
CAM/224/05/12/NVD

CONTENTS

SECTION	PAGES
Introduction	1
Background	1
Relevant Standards	2
Assessment Procedure	2
Analysis	4
Results	5
Discussion	6
Conclusions	9
Recommendations	10
Acknowledgements	10
ANNEXES	
Annex A – Aircraft Layout and Seating	A-1
Annex B – Measured Data Acquired During Chinook Assessment Sorties	B-1
Annex C – Octave Band Insertion Loss Figures for Aircrew Mk4 Helmet and Passenger Mk 15 Helmet	C-1
Annex D – Numerical Data for the Ambient Noise and the Calculated Protected Level	D-1

OCCUPATIONAL AND ENVIRONMENTAL MEDICINE WING

NOISE AND VIBRATION DIVISION

ROYAL AIR FORCE CENTRE OF AVIATION MEDICINE

Report No: OEM/16/06

A REPORT ON AN IN-FLIGHT NOISE ASSESSMENT OF RAF ODIHAM CHINOOK AIRCRAFT CREW DURING NORMAL TRAINING SORTIES

Author: [redacted]

REFERENCES

A. RAF CAM Tasking Proforma CAM/224/05/12/NVD dated 2 Aug 05.
B. European Directive 2003/10/EC (Physical Agents (Noise) Directive).
C. Control of Noise at Work Regulations 2005.
D. JSP 375 Vol 2 Lft 6.
E. Noise at Work Regulations 1989 (NAWR).
F. Reducing Noise at Work – Guidance on the Noise at Work Regulations 1989, pp36, Para 152.
G. BS EN 24869-1: Acoustics. Hearing Protectors. Sound attenuation of hearing protectors. Subjective method of measurement 1993.

INTRODUCTION

1. The Noise and Vibration Division (NVDiv) of the RAF Centre of Aviation Medicine (RAF CAM) was tasked at Reference A by CHE1 of the Chinook IPT to perform a noise exposure survey of personnel inflight during sorties on board Chinook aircraft of 18 Sqn and 27 Sqn at RAF Odiham in Hampshire. The work undertaken by the NVDiv was performed under the purview of a tasking instigated by Eng Pol AW and SHEF covering all aircraft types and variants in the RAF Fleet, prompted by the implementation into UK legislation of the European Physical Agents (Noise) Directive (PA(N)D) (Reference C) as the Control of Noise at Work Regulations 2005 (Reference D).

2. The noise assessment was carried out for the Chinook aircrew during training sorties, on 19–23 Sep 05.

BACKGROUND

3. The introduction of the UK Noise regulations at Reference C has the potential to limit the operating time for Chinook crews unless steps are taken to mitigate the hazards. The Chinook IPT has not been able to identify any previous noise survey and is unsure of the extent of the problem or the actions that will need to be taken to meet the requirement of the regulations.

4. The Chinook aircraft is a heavy-lift support helicopter and is primarily used for trooping and for load carrying (both internal and underslung) and can carry up to 54 troops or 10 tonnes of freight. The cabin is large enough to accommodate 2 Land Rovers, while the 3 underslung load hooks allow flexibility in the type and number of loads that can be carried. Secondary roles include Search and Rescue and Casualty Evacuation. The crew of 4 consists of either 2 pilots or a pilot and navigator and 2 loadmasters. The Chinook is unique in the RAF fleet in that it has 2 main rotors instead of a main rotor and tail rotor.

5. Hearing protection for the aircrew (pilots, navigators and loadmasters) consists of the Mark 4B-/4L Helmet (NSN 22C/8415-99-0005550/1/2/3/4) or Mk 4A4 Helmet (NSN 22C/8415-99-7703105/6/7/8/9). This is used to monitor internal and external communications channels. During night flying Night Vision Goggles are attached. Rear seat passengers and ground crew are issued with Aearo Classic earplugs NSN 6515-00-126-3570 if they are wearing an issue Kevlar helmet. If passengers do not have a helmet they are issued with a Mk 15 Passenger helmet (NSN 22C/8457-99-9736861) which can be used to monitor communication channels.

RELEVANT STANDARDS

6. The occupational noise exposure to crew personnel is currently assessed in accordance with References D and E. In order to prevent noise induced hearing loss, References D and E set a number of action levels. The First Action Level (FAL) is set at a daily personal exposure level ($L_{EP,d}$) of 85dB(A), the Second Action Level (SAL) at an $L_{EP,d}$ of 90dB(A) and the Peak Action Level is set at a C-weighted instantaneous Sound Pressure Level (L_{Cpk}) of 140dB(C).

7. The new PA(N)D at Reference B sets new action and limit values for daily exposure to noise. Following consultation with relevant bodies, this directive has been implemented into UK law effective from 6 Apr 06, as the Control of Noise at Work Regulations 2005 at Reference C. The directive sets a Lower Exposure Action Value (LEAV) for continuous noise at an $L_{EP,d}$ of 80dB(A), an Upper Exposure Action Value (UEAV) for continuous noise at an $L_{EP,d}$ of 85dB(A) and an Exposure Limit Value (ELV) at an $L_{EP,d}$ of 87dB(A). The use of a weekly noise exposure level ($L_{EP,w}$) is also defined, based on a 5-day, 40 hour working week. For impulsive (peak) noise, the LEAV is set at an L_{Cpk} of 135dB(C), the UEAV is set at an L_{Cpk} of 137dB(C) and the ELV is set at an L_{Cpk} of 140dB(C). For both continuous and impulsive noise, the ELV includes the effect of hearing protection. It is unlikely that the aircrew on board the Chinook will be exposed to any excessive impulsive (peak) noise during their normal training sorties, only the continuous noise and its relevant standards will be considered here.

8. The ELV of 87dB(A) cannot be exceeded legally unless an exemption certificate is granted. The aircraft IPT Leader is responsible for this and must submit a safety case to the Secretary of State for Defence to obtain the exemption. The procedure for obtaining an exemption will be defined in the updated version of Reference D. An exemption will only be granted if noise exposure has been reduced to as low a level as is reasonably practicable.

ASSESSMENT PROCEDURE

9. Measurements were made during a number of flights flying from RAF Odiham during the period 19-23 Sep 05. Table 1 shows the details of the flights made.

Table 1 - Details of the Flights During Which Noise Measurements Were Made

Date	Tail Number	From	To	Approximate Duration (hh:mm)	Type of Flight
19 Sep 05	ZA707	Odiham	Odiham	00:50	Underslung loads
20 Sep 05	ZA670	Odiham	Odiham	00:55	Underslung loads
20 Sep 05	ZA707	Odiham	Odiham	02:35	Low/medium level trooping
21 Sep 05	ZH895	Odiham	Odiham	00:35	Underslung loads
21 Sep 05	ZA670	Odiham	Odiham	02:00	Low/medium level training
22 Sep 05	ZH895	Odiham	Odiham	01:10	Low/medium level pax flight
22 Sep 05	ZA707	Odiham	Odiham	01:10	Low/medium level pax flight
22 Sep 05	ZA673	Odiham	Odiham	01:00	Low/medium level pax flight
23 Sep 05	ZH895	Odiham	South Wales	01:35	Low/medium level trooping
23 Sep 05	ZH 895	South Wales	Odiham	02:55	Low/medium level trooping

10. All noise monitoring equipment was calibrated both before and after measurements using a B&K Type 4231 Acoustic Calibrator which produces reference tones of 94dB and 114dB at a frequency of 1kHz and is traceable to and comparable with, a UKAS reference standard.

11. On boarding the aircraft NVDiv fitted a sample of crew personnel and passengers (comprising NVDiv team members wearing Mk15 Passenger Helmets) with a Knowles 1785 miniature microphone at each ear (under the headset) attached to a Sony PCM-M1 digital audio tape (DAT) recorder, to monitor the at-ear noise exposure. NVDiv personnel were then instructed to take their seats for take-off and climb to cruise altitude. The monitoring equipment remained in place with each crewmember for long enough that a representative sample of noise was obtained, usually for the tape duration of approximately 2 hours and encompassing the entire sortie.

12. Once at cruise altitude (or as soon as permission was given for NVDiv personnel to move around the cabin) NVDiv team members shadowed the monitored crew with B&K 2260 Sound Level Meters (SLM) to give noise levels external to the Mk 4 Helmets worn, for cockpit and rear cabin crew. Measurement positions were recorded in terms of seat number at which the monitored personnel were working. Measurements were also taken with the B&K 2260 at the ear positions of the passenger seating in the rear of the aircraft. These measurements were also recorded in terms of seat number. A plan of the aircraft can be seen at Annex A, Figure 1 showing seat numbers.

13. For descent, circuit work and landing, the DAT recorder noise monitoring equipment remained with the sample of cockpit and rear cabin personnel. It was not possible to use the B&K 2260 SLM during these periods due to the requirement to be strapped in during these manoeuvres.

ANALYSIS

14. The noise exposure levels to which Chinook aircrew can be exposed and time limits which pilots can fly daily or weekly were calculated, based on the assumption that the aircrew spend the rest of the day or week in a quiet environment (less than 80dB(A) at-ear for no more than 8 hours, or time-averaged equivalent).

15. The noise data was analysed using dedicated 01dB Trait and B&K software. The data was used to calculate the period of time each working day that a crewmember can fly, up to an $L_{EP,d}$ noise exposure equivalent to the legislative levels of the current (References D and E) and forthcoming (Reference C) legislation.

16. The forthcoming legislation also allows the full working week to be taken into account. As it is unlikely each crewmember will fly daily, calculations of exposure time limits based on $L_{EX,h}$ will increase the allowable flight time per week. Calculation has been performed, based on measured levels, to ascertain how many flying hours each crewmember can fly within the space of one 40-hour 7-day week before reaching the exposure limits specified in the forthcoming legislation.

17. As all crew positions are in use whenever the Chinook aircraft is inflight it was decided that the single $L_{EP,d}$ value for the aircraft crew would be based on the crewmember having the highest at ear noise level. The values are therefore based on the noise exposure of the most at risk member of the crew.

18. Measured at-ear noise values with and without contribution from the communications system were used to calculate the Signal-to-Noise Ratio (SNR) each crewmember was using during the flights. This indicates the level of volume being selected by the crewmember.

19. Passengers noise data recorded for NVDiv team members wearing the Mk15 Passenger Helmets was analysed using dedicated 01dB Trait and B&K software. As for the aircrew, the data was used to calculate the period of time each working day that a passenger can fly, up to an $L_{EP,d}$ noise exposure equivalent to the legislative levels of the current (References D and E) and forthcoming (Reference C) legislation. As it is unlikely passengers will fly daily, calculation of exposure time limits based on $L_{EX,h}$, to take into account the full working week was also performed.

20. The passive insertion loss of both the aircrew and passenger helmets was calculated using data recorded at the ear during a period in which no communications system noise was present in conjunction with the ambient noise measured at that working position. It should be noted that insertion loss measured in this way is not equivalent to attenuation measured in accordance with Reference G, as it does not take into account the Acoustic Transfer Function of the individual ear. Following the guidance for the current legislation, figures for exposure are calculated using a correction of 1 standard deviation (s.d.) in attenuation figures for hearing protectors (Reference G). The use of a 1 s.d. correction to mean attenuation values means that quoted attenuation figures protect 68% of the population, rather than only 50% which would be the case if only the mean value were used. Proposed new standards use 1 s.d. plus 4dB in order to protect a larger proportion of the populace.

RESULTS

21. The L_{Aeq} values measured on the aircraft are given at Annex B for the noise measured at the ear and the ambient noise in the cockpit (where measured) just outside the communication headsets of the aircrew and passengers aboard the aircraft.

22. The worst case aircrew L_{Aeq} was found to be 94 dB(A). The worst case passenger L_{Aeq} was found to be 101 dB(A), for a passenger on communications.

23. Allowable exposure time limits at which the daily or weekly (where applicable) noise exposure limits given in the current legislation at Reference D and E and the forthcoming legislation at Reference C are reached for aircrew are given in Tables 2 and 3 below. Again, the values are based on the highest at-ear noise monitored. These values include no noise contribution for the rest of the day or the week.

Table 2 - Allowable Exposure Daily Time Limits

Level in dB(A)	80*	85**	87*
Allowable Time Period of Exposure (hh:mm)	00:19	01:00	01:35

Table 3 - Allowable Exposure Weekly Time Limits

Level in dB(A)	80*	85*	87*
Allowable Time Period of Exposure (hh:mm)	01:35	05:02	07:58

* Forthcoming Legislation
** Current and Forthcoming Legislation

24. Allowable exposure time limits at which the daily or weekly (where applicable) noise exposure limits for the passengers given in the current legislation at References D and E and the forthcoming legislation at Reference C are reached are given in Tables 4 and 5 below. Again, the values are based on the highest at-ear noise monitored. These values include no noise contribution for the rest of the day or the week.

Table 4 - Allowable Exposure Daily Time Limits for Passengers

Level in dB(A)	80*	85**	87*
Allowable Time Period of Exposure (hh:mm)	00:03	00:12	00:19

* Forthcoming Legislation
** Current and Forthcoming Legislation

Table 5 - Allowable Exposure Weekly Time Limits

Level in dB(A)	80*	85*	87*
Allowable Time Period of Exposure (hh:mm)	00:19	01:01	01:37

* Forthcoming Legislation
** Current and Forthcoming Legislation

25. Octave band insertion loss figures for the Aircrew Mk 4 Helmet and the passenger Mk 15 Helmet, averaged over all personnel monitored, are given at Annex C, Tables 1 and 2, respectively.

26. Table 1 at Annex D gives the numerical data for the ambient noise and the calculated protected level to which each passenger would be exposed in that seat, based on the manufacturer supplied attenuation figures for the Aearo Classic foam earplug. The worst case exposure is an ambient L_{Aeq} of 106 dB(A), corresponding to a protected level of 69 dB(A). For this protected level, i.e. with correctly fitted Aearo Classic foam earplugs, there are no flying time restrictions either daily or weekly for rear seat passengers.

DISCUSSION

27. The levels of noise exposure are calculated for the worst case, of a crewmember having the highest at-ear noise dose recorded during the 10 flights. This has been done as the legislation which drives this noise survey requires assessments to be person specific, rather than job specific, to take into account the fit of hearing protection etc. As stated at Reference F, the Health and Safety Executive recommend that where sampling of a workforce is undertaken the worst case should be used for calculations of noise exposure.

28. The results calculated for the aircraft, based on the worst case measured value, are in excess of the noise levels recommended in both the current and forthcoming legislation, leading to reduced sortie lengths being advised should the current situation continue (Tables 2 and 3). It should be noted that these limiting periods should be taken from engine start to engine stop as communications are monitored during this period and engine noise is present. In practice these time limits are unworkable given the nature of the task for which the Chinook is intended. Therefore some noise mitigation is necessary in order to protect crewmembers aboard this aircraft from Noise Induced Heating Loss (NIHL) when flying sorties.

29. Table 1 at Annex B gives L_{Aeq} values for the aircrew monitored showing their protected levels without communications SNR (ie, measured with the headset unplugged from the communications system or when no communications noise is present in the recording). As can be seen, these noise levels are significantly in excess of 80dB(A) for the greater proportion of aircrew monitored. For this reason it will be necessary to reduce the attenuated at-ear noise levels significantly to allow the addition of communications content without breaching the 80dB(A) action value of the forthcoming legislation. It should be noted that a SNR of 10dB(A) is the accepted requirement for intelligible speech communications and in most cases Chinook aircrew are below this level, showing they are effectively adjusting their

communications volume to minimise noise exposure. Measured levels above this may be due to poor quality of the communications system, faint and garbled signals being deciphered and/or poor training of crew in terms of the use of the communications system.

30. Table 2 at Annex B gives this information for the passengers monitored. As can be seen noise levels without communications are higher than for aircrew, meaning the Mk15 helmet has provided less protection than the Mk4. The SNR is in reasonable correlation with that used by aircrew, although no volume control is provided to passengers. Caution should be used when using these figures for weekly averaging (as in Table 5, above) as the assumption that passengers spend the remainder of the week in a quite environment may be spurious as their activities are not predictable. This could lead to an underestimate of their true noise dose.

31. Technically the FAL and SAL of the forthcoming legislation can be exceeded; the requirement is for action to be taken (the ELV of 87dB(A) cannot be exceeded). Actions required by employers exceeding the FAL and SAL to protect employees are detailed in the forthcoming legislation. The Control of Noise at Work Regulations 2005 state: "*If any employee is likely to be exposed to noise at or above an upper exposure action value, the employer shall reduce risk to a minimum by establishing and implementing a programme of organisational and technical measures, excluding the provision of personal hearing protectors, which is appropriate to the activity and consistent with the risk assessment, and shall include consideration of:*

(a) Other working methods which eliminate or reduce exposure to noise.

(b) Choice of appropriate work equipment emitting the least possible noise, taking account of the work to be done.

(c) The design and layout of workplaces, work stations and rest facilities.

(d) Suitable and sufficient information and training for employees, such that work equipment may be used correctly, in order to minimise their exposure to noise.

(e) Reduction of noise by technical means including:

(i) In the case of airborne noise the use of shields, enclosures and sound absorbent coverings; and

(ii) In the case of structure-borne noise by damping and isolation.

(f) Appropriate maintenance programmes for work equipment, the workplace and workplace systems.

(g) Limitation of the duration and intensity of exposure to noise; and

(h) Appropriate work schedules with adequate rest periods.

32. According to the forthcoming legislation the employer shall only resort to the provision of hearing protection if the above measures are unsuccessful in reducing the noise

levels to below the SAL. If the ELV is exceeded the employer is bound to reduce the exposure to below the limit value.

33. The 3-stage process of controlling excessive noise exposure of employees is defined at Reference E. This details the preferred order in which noise attenuating measures should be taken. It is stated that the noise should first be controlled at source, meaning steps should be undertaken to reduce the unwanted noise being generated from the process. The second stage is to control noise in the path between the source and employee, usually involving barriers, absorbent materials and separation of the source and employee. The third and least preferred stage involves issuing suitable Personal Protective Equipment (PPE) to employees exposed to noise.

34. As it is unlikely to be possible to significantly reduce the noise at source, given that this would be the engine noise and airflow noise over the airframe, the ideal method of reducing the at-ear noise would be to reduce the ambient noise levels in the cabin of the Chinook. Several approaches would be feasible given current and proposed technologies. Noise insulating and absorptive materials could be considered as cladding for hard console surfaces and the interior of the aircraft fuselage as a means of reducing noise levels. Given that space and weight is at a premium on board the aircraft, effective incorporation of enough of these materials to reduce the noise levels would be difficult. Companies such as QinetiQ would be able to give advice and perform research into the feasibility of this approach. NVDiv can advise on suitable companies and act as subject matter experts on behalf of the Chinook IPT if required. These materials are also under constant development and a programme of 'technology watching' should be implemented.

35. Research has been conducted into Volumetric Active Noise Cancellation (ANC) within aircraft fuselages using a matrix of microphones and speakers to produce destructive interference and reduce noise levels. This technology is in its infancy and would be prohibitively expensive to implement at present, but should again be incorporated into a programme of 'technology watching' for future aircraft upgrades. Again companies such as QinetiQ are undertaking research into this approach and the NVDiv is available to advise the Chinook IPT as subject matter experts.

36. It is accepted that during operational use it may be necessary to use an undesirably high SNR during some activities such as when weapons are fired in the rear. For this reason it is not suggested that the communications system be fitted with gain limiters. However, the implementation of a warning light on each console, activated by the use of a SNR above 12dB(A), is recommended. This would allow both the operator of the console and their Ranking Officer aboard the aircraft to be aware that undesirable levels were being used and that the situation needed to be addressed and corrected if necessary during routine or training sorties.

37. High communications SNR levels can be a product of poor quality audio, such as high levels of static and feedback or interference. The communications system fitted to each of the aircraft should be tested and repaired if necessary. The implementation of selectable electronic filters into the communications system should be considered to improve the quality of the audio. Also a 'bandpass' filter specific to voice communication frequencies accepted to be necessary for clear speech intelligibility, 300 Hz to 5000 Hz, would be effective in reducing

exposure to unnecessary signals and system noise. Quality of the reproduced signal should be a consideration when any upgrades to the communications system are undertaken.

38. The helmets currently worn by the crewmembers and passengers should be reviewed in favour of a hearing protector with a higher attenuation to minimise unwanted noise at the ear. The highest attenuation helmet with a communications facility available should be procured as soon as possible. The fitting of Active Noise Reduction systems to the helmet chosen should also be investigated; however this is a secondary consideration to high passive attenuation.

39. Due to high levels of ambient noise, crewmembers and passengers should be advised to wear dual protection of Aero Classic foam earplugs (NSN 6515-99-126-3570) beneath their helmets. This will give further protection from ambient noise levels. The communications volume can be adjusted to give a suitable SNR over the protection of the earplug. It is accepted that this solution may cause discomfort and is suggested as an interim measure prior to the procurement of a superior helmet. Passengers should be instructed in the proper use of foam earplugs before being taken to the aircraft and should be placed on communications only when necessary.

40. The aircraft crews should be given information on the causes and effects of NIHL and how to minimise the risks in their working environment. This should include instruction to use only the very minimum SNR (volume level) they require to understand the messages, to listen to only those channels it is necessary for them to monitor and to only monitor the communications channels when it is necessary to do so.

41. Future modification to the aircraft (for example, additional external antennae (which produce aerodynamic noise), engine upgrades, rotor blade upgrades, interior equipment upgrades etc.) should be performed with interior noise levels as a constraining factor.

42. As stated above, the ELV of 87dB(A) cannot be exceeded legally unless an exemption certificate is granted. The aircraft IPT leader is responsible for this and must submit a safety case to the Secretary of State for Defence to obtain the exemption. The procedure for obtaining an exemption will be defined in the updated version of Reference D. An exemption will only be granted if noise exposure has been reduced to as low a level as is reasonably practicable.

CONCLUSION

43. The noise levels to which Chinook aircrew and passengers are being exposed are too high in terms of both current legislation (References D and E) and forthcoming legislation (Reference C). Crewmembers flying sorties exceeding the periods of time given at Table 2 and Table 3 are at risk of NIHL. These sortie times should be taken to encompass the entire high noise period i.e. from engine start to engine stop, as engine noise is present and communications are monitored throughout.

44. Noise levels at the ear must be reduced in order to allow the Chinook aircraft to fly sorties without the crewmembers and passengers being exposed to average levels exceeding the limits defined in the legislation. This can be achieved by reducing the ambient cabin noise and increasing the level of hearing protection offered to the crew.

45. Training in the use of the communications system should be introduced so that it can be assured only the minimum SNR necessary to the task is used. Passengers wearing the Mk15 Helmet should be placed on communications only when necessary.

RECOMMENDATIONS

46. As a result of this work it is recommended that:

a. Time limits for exposure of Chinook aircrew should include the entire period of noise exposure, from engine start to engine stop.

b. A helmet offering a higher level of attenuation be investigated and procured. It may be possible to upgrade the current helmet to offer higher levels of protection and this should be considered in competition with other available competitors.

c. Crewmembers should be informed they are at risk of NIHL and offered the use of Aero Classic foam earplugs (NSN 6515-99-126-3570) beneath their helmets. Instruction should be given in their proper use.

d. Passengers wearing Mk15 helmets should only be placed on communications if necessary. All passengers should be required to wear Aero Classic foam earplugs (NSN 6515-99-126-3570) at all times and instructed in their proper use.

e. The aircraft crews and passengers should be given information on the causes and effects of NIHL and how to minimise the risks in their working environment.

f. Future modification to the aircraft (for example, additional external antennae (which produce aerodynamic noise), engine upgrades, interior equipment upgrades etc) should be performed with interior noise levels as a constraining factor.

47. Further consideration is recommended to:

a. Fitment of warning lights to each console to make both the crewmember and line manager aware that excessive SNR levels are being used.

b. Modification to the communications system to include adjustable filters and bandpass filters to improve the quality of the audio and minimise the unnecessary frequencies to which crewmembers are exposed.

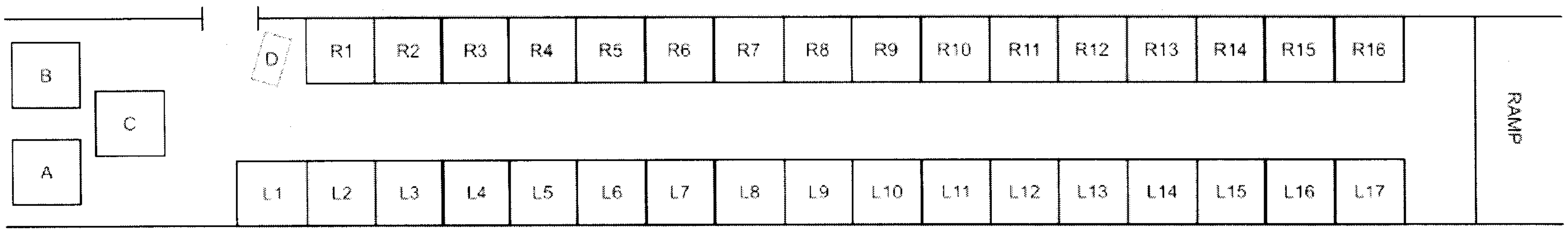
c. Implement technology watching in areas discussed above in order to be aware when other applicable techniques for noise reduction reach maturity.

ACKNOWLEDGEMENTS

48. The NVDiv of the RAF CAM would like to acknowledge the assistance of the Chinook IPT and the personnel of 18 Sqn and 27 Sqn at RAF Odiham. The survey team consisted of [redacted] (NV1), [redacted] (NV4a), [redacted] (NV2a) and [redacted] (NV1b).

AIRCRAFT LAYOUT AND SEATING

Figure 1: Diagram Showing Aircraft Layout and Seating



Key:

A - Left-hand Pilot
B - Right-hand Pilot
C - Jump Seat
D - Forward Loadmaster's Improvised Seat

L1-16 - Left-hand Passenger Seats
R1-16 - Right-hand Passenger Seats

MEASURED DATA ACQUIRED DURING CHINOOK ASSESSMENT SORTIES

Table 1 - Measured Data Acquired During Chinook Assessment Sorties for Aircrew Wearing Mk4 Helmets

	At Ear Noise Levels				Ambient Noise Levels		
Tape Number	L_{Aeq} with comms/ dB(A)	Duration/ hh:mm	L_{Aeq} without comms dB(A)	Duration mm:ss	L_{Aeq} dB(A)	Duration mm:ss	Comms SNR/dB
MP1	87.4	01:20:35	77.2	00:00:27	104.3	0:00:31	10.4
GH1	88.7	01:00:03	80.1	00:00:27	104.3	0:00:31	10.3
MP4	81.9	00:08:17	73.0	00:00:04	106.2	0:00:30	14.0
GH3	94.0	01:59:24	77.9	00:00:33	102.3	0:00:30	5.9
MP7	90.2	01:58:12	85.7	00:00:32	-*	0:00:32	7.5
E3	92.6	01:43:46	86.6	00:00:24	-*	0:00:32	5.0
MP6	87.7	02:00:55	84.7	00:00:30	100.2	0:00:33	3.9
GH9	87.2	01:06:44	82.6	00:00:30	-*	0:00:30	6.0
E4	89.4	01:31:53	81.5	00:00:26	104.1	0:00:32	11.4
E5	91.2	01:30:37	88.2	00:00:23	105.1	0:00:31	3.7
E6	89.4	01:31:53	83.7	00:00:26	107.5	0:00:30	7.7
AH2	88.2	01:44:13	84.7	00:00:24	N/A	N/A	4.9
E7	90.0	01:45:56	84.6	00:00:24	N/A	N/A	6.5
E8	86.5	01:41:30	80.2	00:00:21	104.1	0:00:32	7.4
AH4	88.1	01:14:48	84.0	00:00:30	107.5	0:00:30	3.0
P1	83.9	01:42:54	84.2	00:00:33	101.0	0:00:31	9.2

* - Data not available due to measurement equipment failure

Table 2 - Measured Data Acquired During Chinook Assessment Sorties for Passengers Wearing Mk15 Helmets

	At Ear Noise Levels				Ambient Noise Levels		
Tape Number	**L_{Aeq} with comms/ dB(A)**	**Duration/ hh:mm**	**L_{Aeq} without comms dB(A)**	**Duration mm:ss**	**L_{Aeq} dB(A)**	**Duration mm:ss**	**Comms SNR/dB**
MP2	89.9	01:14:30	80.8	00:00:40	101.8	0:00:29	6.7
MP3	100.9	01:21:33	83.8	00:00:30	104.1	0:00:31	17.6
E1	94.1	01:53:44	87.3	00:00:33	N/A	N/A	5.6
AH1	91.5	01:59:09	87.4	00:00:31	N/A	N/A	6.9
GH10	84.9	00:54:39	80.5	00:00:25	77.2	0:00:31	5.3
GH11	88.5	01:18:57	82.1	00:00:28	N/A	N/A	8.5
GH12	97.6	01:19:29	92.2	00:00:57	101.0	0:00:31	8.1
AH3	97.4	01:25:22	92.5	00:00:31	N/A	N/A	8.5

OCTAVE BAND INSERTION LOSS FIGURES FOR AIRCREW MK 4 HELMET AND PASSENGER MK 15 HELMET

Table 1 - Average Measured Insertion Loss Values for the Mk 4 Helmet Worn by Chinook Aircrew

Frequency Band/Hz	63	125	250	500	1000	2000	4000	8000
Mean/dB	8.7	9.2	17.3	27.9	41.5	45.3	51.8	43.6
S.D./dB	4.4	4.2	6.8	3.2	6.5	5.2	3.7	2.0

Table 2 - Average Measured Insertion Loss Values for the Mk 15 Helmet Worn by Chinook Passengers

Frequency Band/Hz	63	125	250	500	1000	2000	4000	8000
Mean/dB	12.0	13.9	6.7	19.7	32.9	30.7	41.8	47.5
S.D./dB	9.8	10.3	3.6	4.3	3.9	5.2	10.5	5.0

NUMERICAL DATA FOR THE AMBIENT NOISE AND THE CALCULATED PROTECTED LEVEL

Table 1 - Measured Ambient Noise Levels for Chinook Seating with Calculated Protected L_{Aeq} Values for Passengers Wearing Aearo Classic Foam Earplugs

Seat Number	Ambient L_{Aeq} /dB(A)	Protected L_{Aeq}/dB(A)
L1	99.7	64.24
L2	101.7	67.83
L3	104.3	67.69
L4	98.4	62.01
L5	99.1	63.49
L6	98.2	61.76
L7	98.6	62.51
L8	99.1	63.50
L9	100.5	64.62
L10	102	66.39
L11	102.4	66.98
L12	102.3	66.79
L13	106.2	69.32
R1	99.3	61.65
R2	98.6	62.61
R3	100.4	62.82
R4	97.4	62.44
R5	97.9	62.15
R6	98.2	62.17
R7	98.7	62.17
R8	100	62.17
R9	100	62.35
R10	101.1	63.10
R11	103.4	63.87
R12	104.5	65.07
R13	105.6	66.45
Left Hand Pilot Seat	104.1	N/A
Jumpseat	102.9	N/A
Right Hand Pilot Seat	105.1	N/A

OCCUPATIONAL AND ENVIRONMENTAL MEDICINE WING

NOISE AND VIBRATION DIVISION

Report: OEM/36/13 Dated June 2013

A REPORT ON AN INFLIGHT NOISE ASSESSMENT OF PUMA HC2 AIRCREW DURING REPRESENTATIVE SORTIES AT MOD BOSMCOMBE DOWN

Approved for publication

[redacted]
Head of the
Noise and Vibration Division

Date

CONDITIONS OF RELEASE

OCCUPATIONAL AND ENVIRONMENTAL MEDICINE WING
NOISE AND VIBRATION DIVISION

ROYAL AIR FORCE CENTRE OF AVIATION MEDICINE

Report No: OEM/36/13

A REPORT ON AN INFLIGHT NOISE ASSESSMENT OF PUMA HC2 AIRCREW DURING REPRESENTATIVE SORTIES AT MOD BOSCOMBE DOWN

EXECUTIVE SUMMARY

1. The Noise and Vibration Division of the RAF Centre of Aviation Medicine was tasked by Mr A. Ridout of Defence, Engineering and Science, Puma HC2 Project Team to perform a noise assessment for the Left Hand Pilot, Right Hand Pilot, Jump Seat and Cabin aircrew positions in the Puma HC2 Aircraft during representative sorties. The noise assessment for the Puma HC2 aircrew was carried out at MOD Boscombe Down on 06 Mar 13.

2. The Puma HC2 aircraft is a medium transport helicopter used by the RAF. The aircraft supports 3 seated aircrew and 13 passengers.

3. Where sampling of a workforce is undertaken, the worst case should be used for calculations of noise exposure. This is because noise assessments are required to be person specific, rather than job specific, to take into account the fit of hearing protection etc. and ensure that the whole workforce is protected in the "real world" conditions measured, so far as is reasonably practicable.

4. Using the worst case measured ambient noise, the results show that an individual in the position of Right Hand Pilot wearing Alpha 928 with Communication Ear Plugs reaches the Lower Exposure Action Value after 1 hour; the Upper Exposure Action Value after 3 hours 11 minutes; and the Exposure Limit Value after 5 hours 2 minutes.

5. Using the worst case measured ambient noise, the results show that an individual in the position of Right Hand Pilot wearing Mk 4A4 with Communication Ear Plugs reaches the Lower Exposure Action Value after 2 hours 31 minutes; the Upper Exposure Action Value after 8 hours; and the Exposure Limit Value after 12 hours 40 minutes.

6. Using the worst case measured ambient noise, the results show that an individual in the position of the Jump Seat wearing Alpha 928 with Communication Ear Plugs reaches the Lower Exposure Action Value after 48 minutes; the Upper Exposure Action Value after 2 hours 31 minutes; and the Exposure Limit Value after 4 hours.

7. Using the worst case measured ambient noise, the results show that an individual in the position of the Jump Seat wearing Mk 4A4 helmet with Communication Ear Plugs reaches the Lower Exposure Action Value after 2 hours; the Upper Exposure Action Value after 6 hours 21 minutes; and the Exposure Limit Value after10 hours 4 minutes.

8. Using the worst case measured ambient noise, the results show that an individual in the Cabin wearing Alpha 928 with Communication Ear Plugs reaches the Lower Exposure Action Value after 15 minutes; the Upper Exposure Action Value after 48 minutes; and the Exposure Limit Value after 1 hour 16 minutes.

9. Using the worst case measured ambient noise, the results show that an individual in the Cabin wearing Mk4A4 helmet with Communication Ear Plugs reaches the Lower Exposure

Action Value after 30 minutes; the Upper Exposure Action Value after 1 hour 35 minutes; and the Exposure Limit Value after 2 hours 31 minutes.

10. All aircrew should be instructed to reduce the communication signal volume levels to the minimum necessary for clear, unambiguous understanding. All aircrew should be aware that others on the communications system do not have control over the volume and adjust it accordingly. Therefore it is recommended that the communications system should be modified to enable independent volume control for each user. It should be noted that an SNR of 10 to 15dB is the generally accepted requirement for intelligible speech. During operational scenarios it may be necessary to use undesirably high Signal to Noise Ratio during some activities. For this reason it is not suggested that the communications system be fitted with limiters. However, the implementation of a warning light on each console, activated by the use of Signal to Noise Ratio above 15dB, is recommended

11. Noise levels at the ear should be reduced in order to allow the Puma HC2 aircrew to operate without personnel being exposed to average levels exceeding the action and limit values defined in legislation. To achieve this it is necessary to reduce the ambient noise as far as practicable and improve the hearing protection provided to aircrew and passengers.

12. As a result of this survey, it is recommended that:

a. A good fit of helmet needs to be ensured.

b. Aircrew should be informed that they are at risk of NIHL and be instructed to use the minimum feasible volume of communications.

c. The MOD standard Communication Ear Plug is adopted.

d. Modify the communications system to enable independent volume control.

e. Further assessments to include additional airframes and aircrew are undertaken. This will increase the sample size of the data collected and improve the reliability of results.

13. This report does not comprise a risk assessment for the activities detailed within. It contains the information necessary to undertake an assessment of risk. A risk assessment should be carried out by the line management of exposed personnel.

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CONTENTS

SECTIONS	PAGES
Introduction	1
Background	1
Relevant Criteria and Legislation	2
Assessment Procedure	3
Analysis	3
Results	4
Discussion	5
Conclusions	7
Recommendations	8
Acknowledgements	9
References	10

ANNEXES

A. The 'Exposure Points' System for Assessing for Noise Exposure	A-1
B. Guidance Notes on Undertaking a Noise Risk Assessment Using the 'Exposure Points' System.	B-1
C. Measurement Equipment Used During the Survey	C-1
D. Glossary of Terms	D-1
E. Measurement Data Acquired During Puma HC2 Assessment Sorties	E-1
F. Employers Actions Under The Control of Noise At Work Regulations	F-1
G. Report Summary	G-1

OCCUPATIONAL AND ENVIRONMENTAL MEDICINE WING

NOISE AND VIBRATION DIVISION

ROYAL AIR FORCE CENTRE OF AVIATION MEDICINE

Report No: OEM/36/13

A REPORT ON A NOISE ASSESSMENT OF PUMA HC2 AIRCREW DURING REPRESENTATIVE SORTIES AT MOD BOSCOMBE DOWN

Author: [redacted]

INTRODUCTION

1. The Noise and Vibration Division of the RAF Centre of Aviation Medicine was tasked at Reference A by [redacted] of Defence, Engineering and Science, Puma HC2 Project Team to perform a noise assessment for various aircrew positions in the Puma HC2 aircraft during representative sorties.

2. The noise assessment for the Puma HC2 aircrew was carried out at MOD Boscombe Down on 06 Mar 13.

BACKGROUND

3. The Puma HC2 aircraft is a medium transport helicopter used by the RAF. The aircraft supports 3 seated aircrew members and 13 passengers as shown below in Figure 1.

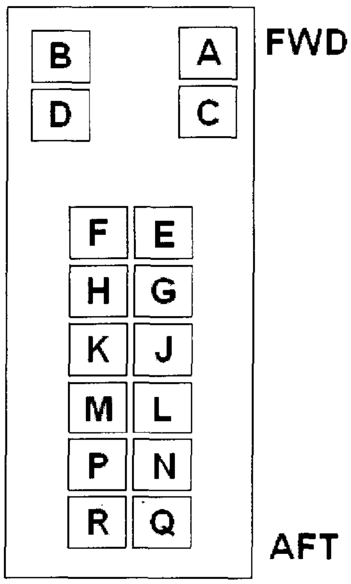

Figure 1 – Seat Layout of Puma HC2 Aircraft

4. In the first sortie the Right Hand Pilot (RHP) (Position A, Figure 1) was equipped with an Alpha 928 Helmet with Communication Ear Plugs (CEP), the Left Hand Pilot (LHP) (Position B, Figure 1) and the individual in the cabin (Cabin) (moved periodically between Positions E to R, Figure 1) were both equipped with Mk 4A4 Helmets with CEP. The Jump Seat (JS) (a folding seat positioned roughly between Position A and B, Figure 1) occupant was equipped with a Mk

4A4 Helmet without CEP. During the second sortie the RHP was equipped with a Mk 4A4 Helmet with CEP, the LHP and Cabin were both equipped with Alpha 928 Helmets with CEP and the JS was equipped with a Mk 15 Passenger Helmet without CEP.

RELEVANT LEGISLATION AND GUIDANCE

5. MOD policy on noise at work is based upon Reference B and is defined at Reference C. References B and C define action and limit values for daily exposure to noise normalised to an 8-hour working day. They define a Lower Exposure Action Value (LEAV) for continuous noise at an $L_{EP,d}$ of 80dB(A), an Upper Exposure Action Value (UEAV) for continuous noise at an $L_{EP,d}$ of 85dB(A), and an Exposure Limit Value (ELV) at an $L_{EP,d}$ of 87dB(A). In circumstances where the noise exposure varies markedly from day to day, or where the working week comprises 3 or fewer days of exposure, the regulations allow the use of weekly noise exposure action and limit values.

6. The ELV of 87dB(A) cannot be exceeded legally unless an exemption certificate is granted. A case must be submitted to the Secretary of State. This will require input from operating authorities; acquisition teams; medical personnel; and relevant subject matter experts. The procedure for obtaining an exemption is defined at Reference C. An exemption would only be granted if noise exposure has been reduced to as low a level as is reasonably practical.

7. The standard unit of noise level measurement is the decibel (dB). To make an understanding of noise dosage easier for employers and employees to understand, the Health and Safety Executive (HSE) at Reference D has introduced a points system whereby the noise doses are allocated a certain number of points. When performing a number of duties with different noise levels and durations, the cumulative noise dose can be calculated by summing the exposure points for each task to obtain a total exposure point value. This value can be compared to the various action and limit values to determine risk. The HSE set the LEAV at 32 points, the UEAV at 100 points and the ELV at 160 points. Annex A shows the HSE 'Exposure Points' system for assessing noise exposure.

8. Reference B states that a hearing protector/helmet/headset that is intended to be used as hearing protection should be CE marked and hence has been tested in accordance with and complies with the relevant part of Reference E.

9. This report does not comprise a risk assessment for the activities detailed within. It contains the information necessary to undertake an assessment of risk. A risk assessment should be carried out by the line management of exposed personnel. Guidance documenting the assessment of risk can be found at Annex B.

ASSESSMENT PROCEDURE

10. Table 1 provides information about the positions at which measurements were made during each sortie.

Table 1 – Details of the Sorties During which Noise Measurements were made

Date	Sortie Number	Airframe	Positions Measured	Type of Flight
06/03/13	1	XW216	LHP	Circuits
		XW216	RHP	
		XW216	JS	
		XW216	Cabin	
06/03/13	2	XW216	LHP	Circuits
		XW216	RHP	
		XW216	JS	
		XW216	Cabin	

11. Measurements were made during 2 representative sorties that took place on 06 Mar 13.

12. During the both sorties the LHP, RHP, JS and Cabin positions were surveyed.

13. All noise monitoring equipment was calibrated both before and after measurements using Brüel & Kjær Type 4231 Acoustic Calibrators which produce a reference tone of 94dB at a frequency of 1kHz, and are traceable to and comparable with a UKAS reference standard.

14. Before boarding the Puma HC2, NVD personnel fitted the subject aircrew with Knowles 1785 miniature microphones, one at the ear (under the headset) and one taped onto the shoulder. The output from the microphones was fed to an Edirol R-09 solid state recorder, which was housed in the flying suit of the aircrew. The monitoring equipment remained in place with each subject for the entire flight.

15. A list of measurement equipment used during the survey and calibrators is given at Annex C.

16. A Glossary of Terms used in the report is given at Annex D.

ANALYSIS

17. Measurement data was imported into 01dBTrait software and octave band L_{eq} in dB, were analysed. This method is in accordance with Reference D. Octave band L_{eq} were averaged for the duration of the sortie, from the time the engine was turned on until the engine was turned off. British Standard test attenuation data (Reference E) was then subtracted. The results were A-weighted and then logarithmically added. A 4dB real world correction was then applied to allow for poor fitting in accordance with Reference D. A further 15dB Signal to Noise Ratio (SNR) was then added to allow for worst case scenario communications noise.

18. Using 01dBTrait software, the At Ear L_{Aeq} for Mk15 Helmet was calculated from the measurements recorded during the assessment because British Standard test attenuation data is not available for this helmet.

19. The maximum daily and weekly exposure times were calculated, up to an $L_{EP,d}$ noise exposure equivalent to the action and limit values defined at References B and C. These calculations are based on the assumption that the aircrew spend the rest of the working day or week in a quiet environment (less than 70dB(A) at-ear).

20. The exposure points per 15 minutes of flight were calculated based on the worst case L_{Aeq} for the sorties measured using Equation 1 taken from Reference D:

Equation 1

$$EP_{15} = T.10^{\left[\frac{L_{Aeq}-109.6}{10}\right]}$$

EP_{15} is the number of exposure points per 15 minutes.
T is 900 seconds (15 minutes).
L_{Aeq} is the A weighted equivalent continuous noise level.

21. The legislation also allows the full working week to be taken into account in situations where noise exposure varies markedly from day to day, or where the working week comprises 3 or fewer days of exposure. Calculations of exposure time limit based on $L_{EP,W}$ will increase the allowable working time per week. Calculations have been performed, based on the measured levels, to ascertain how many working hours each aircrew member can work within the space of one 40-hour, 5-day week before reaching the exposure action and limit values defined at References B and C.

RESULTS

22. The L_{Aeq} values measured on the Puma HC2 are given at Annex E for the noise measured at the ear and the ambient noise in the interior just outside the communication headsets of the aircrew on board.

23. Allowable exposure time limits at which the daily or weekly (where applicable) noise exposure action and limit values defined at Reference B and C are reached for the aircrew are given in Tables 2 and 3 below. The values are based on the highest at-ear L_{Aeq} for each position monitored over the 2 representative sorties. These values include no other noise contribution for the rest of the day or the week. Exposure time limits for the LHP are not included as the measured values could not be used due to equipment malfunction.

24. In addition, the Exposure Points values (points per 15 minutes) were also calculated for the worst case for each position, using Equation 1 previously mentioned. Annex A and Reference D provide further information about the use of the HSE Exposure Points system.

Table 2 – Allowable Exposure Time Limits When Wearing Mk 4A4 Helmet and CEP Based on Calculated Noise Data

Position	Calculated At-Ear LAeq/dB	LEAV (hh:mm)		UEAV (hh:mm)		ELV (hh:mm)		Exposure Points per 15 Minutes
		Daily	Weekly	Daily	Weekly	Daily	Weekly	
RHP	85	02:31	12:38	08:00	40:00	12:40	63:23	3.1
JS	86	02:00	10:02	06:21	31:46	10:04	50:21	3.9
Cabin	92	00:30	02:31	01:35	07:58	02:31	12:38	15.6

Table 3 – Allowable Exposure Time Limits When Wearing Alpha 928 Helmet and CEP Based on Calculated Noise Data

Position	Calculated At-Ear LAeq/dB	LEAV (hh:mm)		UEAV (hh:mm)		ELV (hh:mm)		Exposure Points per 15 Minutes
		Daily	Weekly	Daily	Weekly	Daily	Weekly	
RHP	89	01:00	05:02	03:11	15:55	05:02	25:14	7.8
JS	90	00:48	04:00	02:31	12:38	04:00	20:02	9.9
Cabin	95	00:15	01:15	00:48	04:00	01:16	06:20	31.2

Table 4 – Allowable Exposure Time Limits for the JS When Wearing Mk 15 Passenger Helmet based on Measured Noise Data

Position	Measured At-Ear LAeq/dB	LEAV (hh:mm)		UEAV (hh:mm)		ELV (hh:mm)		Exposure Points per 15 minutes
		Daily	Weekly	Daily	Weekly	Daily	Weekly	
JS	89	01:00	05:02	03:11	15:55	05:02	25:14	7.8

DISCUSSION

25. Where sampling of a workforce is undertaken the worst case should be used for calculations of noise exposure. This is to ensure that, so far as is reasonably practicable, the whole workforce is protected in the "real world" conditions measured. Noise assessments are required by legislation to be person specific, rather than job specific to take into account the fit of hearing protection, selected volume and communications usage. It should also be noted that all the measurements were conducted on one airframe (XW216) so there may be some difference in noise level between airframes which is not accounted for in this assessment.

26. A worst case scenario adjustment of 15dB for communications (SNR) was applied due to the small sample size of sorties and single airframe (XW216) measured.

27. Noise levels were recorded of up to 106dB(A) in the cockpit. This exceeds legislated noise LEAV, UEAV and ELV leading to a recommendation of maximum daily and weekly work times should the current situation continue. These recommended exposure limits include no other noise contribution for the rest of the day. Exceeding the LEAV may put the aircrew members at risk of Noise Induced Hearing Loss (NIHL).

28. Using the worst case measured ambient noise, the results show that an individual in the position of RHP wearing Alpha 928 with CEP reach the daily exposure times of the Lower Exposure Action Value after 1 hour; the Upper Exposure Action Value after 3 hours 11 minutes; and the Exposure Limit Value after 5 hours 2 minutes.

29. Using the worst case measured ambient noise, the results show that an individual in the position of RHP wearing Mk 4A4 with CEP reach the daily exposure times of the Lower Exposure Action Value after 2 hours 31 minutes; the Upper Exposure Action Value after 8 hours; and the Exposure Limit Value after 12 hours 40 minutes.

30. Using the worst case measured ambient noise, the results show that the JS wearing Alpha 928 with CEP reach the daily exposure times of the Lower Exposure Action Value after 48 minutes; the Upper Exposure Action Value after 2 hours 31 minutes; and the Exposure Limit Value after 4 hours.

31. Using the worst case measured ambient noise, the results show that the JS wearing Mk 4A4 helmet with CEP reach the daily exposure times of the Lower Exposure Action Value after 2 hours; the Upper Exposure Action Value after 6 hours 21 minutes; and the Exposure Limit Value after10 hours 4 minutes.

32. Using the worst case measured ambient noise, the results show that an individual in the Cabin wearing Alpha 928 with CEP reach the daily exposure times of the Lower Exposure Action Value after 15 minutes; the Upper Exposure Action Value after 48 minutes; and the Exposure Limit Value after 1 hour 16 minutes.

33. Using the worst case measured ambient noise, the results show that an individual in the Cabin wearing Mk4A4 helmet with CEP reaches the daily exposure times of the Lower

Exposure Action Value after 30 minutes; the Upper Exposure Action Value after 1 hour 35 minutes; and the Exposure Limit Value after 2 hours 31 minutes.

34. To allow for day to day variation in noise exposure, or situations where the working week comprises 3 or fewer days of exposure, the regulations allow the use of a weekly noise exposure level. Using the worst case measured ambient noise, the results show that individuals in the position of RHP reach the weekly LEAV after 5 hours 2 minutes; the UEAV after 15 hours 55 minutes; and the ELV after 25 hours 14 minutes when wearing Alpha 928 helmet and CEP.

35. Using the worst case measured ambient noise, the results show that the JS reaches the weekly LEAV after 4 hours; the UEAV after 12 hours 38 minutes; and the ELV after 20 hours 2 minutes when wearing Alpha 928 helmet and CEP.

36. Using the worst case measured ambient noise, the results show that individual in the Cabin reaches the weekly LEAV after 1 hour 15 minutes; the UEAV after 4 hours; and the ELV after 6 hours 20 minutes when wearing Alpha 928 helmet and CEP.

37. The high exposure levels for the individual in the Cabin could be explained by the door being open during flight. Further assessments would be required to determine the impact on individuals in the Cabin of having the door open or closed.

38. The at-ear L_{Aeq} values measured during the sorties shown in Table 1 at Annex E vary from 89dB(A) to 98dB(A). At-ear noise exposure levels are determined from the following factors: the ambient cockpit noise level, the attenuation of the headset and the volume and duration of communications. The attenuation of the headset is mainly affected by fit, maintenance, and whether spectacles or additional headwear are worn.

39. SNR is the difference in at-ear noise experienced with and without communications. This directly relates to the volume of communications that is set by the user. The volume should be set at a minimum level which enables communications to be clearly understood. An SNR value in the region of 10 to 15dB is normally considered to be adequate.

40. An SNR of 10-15dB (Reference F) is the accepted minimum requirement for intelligible speech. Values of SNR lower than the typical region are adequate as long as speech can be understood. Levels above the accepted range are less desirable as they will probably be making the most significant contribution to the aircrew's noise dose. This may mean that aircrew are not effectively adjusting their communications volume. This could be due to a poor quality of the communications system, faint and garbled signals being deciphered and/or poor training of aircrew in terms of the use of the communications system. All aircrew should be aware that others on the communications system do not have control over the volume and adjust it accordingly. Therefore it is recommended that the communications system should be modified to enable independent volume control for each user.

41. The LEAV, UEAV and ELV can be exceeded; the requirement is for action to be taken. Further information can be found at Annex F.

42. According to the legislation the employer shall only resort to the provision of hearing protection if the above measures are unsuccessful in reducing the noise levels to below the UEAV. If the ELV is exceeded the employer is duty-bound to reduce the exposure to below the limit value.

43. The 3-stage process of controlling excessive noise exposure of employees is defined at Reference B. This details the preferred order in which noise attenuating measures should be taken. It is stated that the noise should first be controlled at source, meaning steps should be undertaken to reduce the unwanted noise being generated from the process. The second stage is to control noise in the path between the source and employee, usually involving barriers, absorbent materials and separation of the source and employee. The third and least preferred

stage involves issuing suitable Personal Protective Equipment (PPE) to employees exposed to noise.

44. As it is unlikely to be possible to significantly reduce the noise at source, given that this would be the engine noise, rotor noise and airflow noise over the airframe, the ideal method of reducing the at-ear noise would be to reduce the ambient noise levels in the cockpit of the Puma HC2. Several approaches would be feasible given current and proposed technologies. Noise insulating and absorptive materials could be considered as cladding for hard console surfaces and the interior of the aircraft fuselage as a means of reducing noise levels. Given that space and weight is at a premium on board the aircraft, effective incorporation of enough of these materials to reduce the noise levels would be difficult. Specialist consultancies would be able to give advice and perform research into the feasibility of this approach. NVD can advise on suitable companies and act as subject matter experts on behalf of DES if required. These materials are also under constant development and a programme of 'technology watching' should be implemented.

45. The third option, issuing PPE, is only valid if the helmet/headset is CE marked having been tested in accordance with the relevant part of Reference E.

CONCLUSIONS

46. The noise levels to which the Puma HC2 aircrew are exposed are excessive in terms of both References B and C. The aircrew members in the trial exceeding the LEAV stated in Tables 2 to 4 are at risk of NIHL.

47. Using the worst case measured ambient noise, the results show that individuals in the position of RHP reach the daily LEAV after 1 hour; the UEAV after 3 hours 11 minutes; and the ELV after 5 hours 2 minutes. Using the worst case measured ambient noise, the results show that the JS reaches the daily LEAV after 48 minutes; the UEAV after 2 hour 31 minutes; and the ELV after 4 hours. Using the worst case measured ambient noise, the results show that individual in the Cabin reaches the daily LEAV after 15 minutes; the UEAV after 48 minutes; and the ELV after 1 hour 16 minutes.

48. Using the worst case measured ambient noise, the results show that individuals in the position of RHP reach the weekly LEAV after 5 hours 2 minutes; the UEAV after 15 hours 55 minutes; and the ELV after 25 hours 14 minutes. Using the worst case measured ambient noise, the results show that the JS reaches the weekly LEAV after 4 hours; the UEAV after 12 hours 38 minutes; and the ELV after 20 hours 2 minutes. Using the worst case measured ambient noise, the results show that individual in the Cabin reaches the weekly LEAV after 1 hour 15 minutes; the UEAV after 4 hours; and the ELV after 6 hours 20 minutes.

49. In order to raise the permissible time limits – those of LEAVs and UEAVs – it is necessary to reduce the at-ear noise experienced by the aircrew and passengers.

50. This report does not comprise a risk assessment for the activities detailed within. It contains the information necessary to undertake an assessment of risk. A risk assessment should be carried out by the line management of exposed personnel.

51. The wearing of CEP reduces noise exposure and therefore increase the time aircrew can fly for before reaching the LEAV.

52. A report summary can be found at Annex G.

RECOMMENDATIONS

53. As a result of this survey, it is recommended that:

a. A good fit of headset needs to be ensured.

b. Aircrew should be informed that they are at risk of NIHL and be instructed to use the minimum feasible volume of communications.

c. The MOD standard CEP is adopted.

d. Modify the communications system to enable independent volume control.

54. The aircrew should be given information on the causes and effects of NIHL and how to minimise the risks in their working environment. This should include instruction to:

a. Use only the very minimum volume level they require to understand the messages over background noise (SNR), adjusting the volume control according to the attenuated background noise especially during engine start and taxi.

b. To listen to only those channels it is necessary for them to listen to.

c. To only monitor the communications channels when it is necessary to do so.

55. It is recommended that further consideration is given to:

a. Fitment of warning lights to both consoles to make the aircrew aware that excessive SNR levels are being used.

b. Modification to the communications system to include filters to improve the quality of the audio and minimise the unnecessary frequencies to which aircrew members are exposed.

c. Further assessments to include additional airframes and aircrew are undertaken. This will increase the sample size of the data collected and improve the reliability of results.

56. It is accepted that during operational scenarios it may be necessary to use otherwise undesirably high SNR during some activities. For this reason it is not suggested that the communications system be fitted with limiters. However, the implementation of a warning light on each console, activated by the use of SNR above 15dB, is recommended. This would allow the aircrew to be aware that undesirable levels were being used and levels should be reduced during routine or training sorties. Some consideration of an Automatic Gain Control (AGC) mechanism should be undertaken, but any AGC system should similarly have an override in order to allow higher SNR use when necessary.

57. The communications system fitted to each of the aircraft should be tested and maintained/repaired if necessary. The implementation of electronic filters into the communications system should be considered to improve the quality of the audio. As an example, a 'bandpass' filter specific to voice communication frequencies necessary to prevent loss of speech intelligibility (300Hz to 4000Hz), could be effective in reducing exposure to unnecessary signals and system noise. Quality of the reproduced signal should be a consideration when any upgrades to the communications system are undertaken.

ACKNOWLEDGEMENTS

58. The survey team, which was comprised of [redacted] (Hd NVD), [redacted] (NV1a) and [redacted] (NV1a1) would like to acknowledge the help provided by the personnel of Station Flight at MOD Boscombe Down.

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THE 'EXPOSURE POINTS' SYSTEM FOR ASSESSING NOISE EXPOSURE

Reference:

A. Health and Safety Executive. Controlling Noise at Work. The Control of Noise At Work Regulations 2005. L108. ISBN 0-7176-6164-4.

1. At Reference A, the Health and Safety Executive define an alternative system of noise exposure assessment. It is a simplified method of calculating an individual's noise exposure when they are exposed to a number of different sources. It is designed so that either the individual or the employer can assess and manage their own or their employees individual noise exposure.

2. Table 1 provides the means to calculate personnel's daily noise exposure based on level of noise and duration. It is suitable for both steady and variable noise exposure throughout the day. It allows noise exposure for individual jobs to be converted into points and totalled to find out the total daily exposure. This system will make apparent the jobs that contribute the greatest noise exposure to the total.

Table 1 – Noise Exposure Calculator

Sound Pressure Level, L_{Aeq} (dB)	Duration of exposure (hours)							
	1/4	1/2	1	2	4	8	10	12
105	320	625	1250					
100	100	200	400	800				
97	50	100	200	400	800			
95	32	65	125	250	500	1000		
94	25	50	100	200	400	800		
93	20	40	80	160	320	630		
92	16	32	65	125	250	500	625	
91	12	25	50	100	200	400	500	600
90	10	20	40	80	160	320	400	470
89	8	16	32	65	130	250	310	380
88	6	12	25	50	100	200	250	300
87	5	10	20	40	80	160	200	240
86	4	8	16	32	65	130	160	190
85		6	12	25	50	100	125	150
84		5	10	20	40	80	100	120
83		4	8	16	32	65	80	95
82			6	12	25	50	65	75
81			5	10	20	40	50	60
80			4	8	16	32	40	48
79				6	13	25	32	38
78				5	10	20	25	30
75					5	10	13	15

Table 2 – Points/Noise level converter

Total Exposure Points	Noise Exposure $L_{EP,d}$ (dB)
3200	100
1600	97
1000	95
800	94
630	93
500	92
400	91
320	90
250	89
200	88
160	87
130	86
100	85
80	84
65	83
50	82
40	81
32	80
25	79
20	78
16	77

3. In the noise exposure points scheme, the Lower Exposure Action Value (LEAV) is 32 points ($L_{EP,d}$ of 80dB), the Upper Exposure Action Value (UEAV) is 100 points ($L_{EP,d}$ of 85dB), and the Exposure Limit Value (ELV) is 160 points ($L_{EP,d}$ of 87dB).

4. Table 3 shows a worked example for calculating daily personal noise exposure. In the example, an employee is exposed to a noise level of 80dB for 5 hours; 2 hours at 86dB; 45 minutes at a noise level of 95dB.

Table 3 – Example of Calculating Daily Noise Points

Noise Level	Duration	Notes	Exposure Points
80	5 hrs	No column for 5 hours, so add together values from 4 and 1 hour columns in row corresponding to 80dB.	16 + 4 = 20
86	2 hrs	Directly from table	32
95	45 mins	No column for 45 minutes so add together values from 30 and 15 minute columns in row corresponding to 95dB.	65 + 32 = 97
Total exposure points			149

5. The total exposure points for this case is 20 + 32 + 97 = 149. This breaks the UEAV of 100 points but is within the ELV of 160 points. Using the converter at Table 2 it can be seen that 149 points works out at 86-87dB. The 45 minutes at 95dB provides the single largest contribution to daily noise points.

6. Using this system it is easy to predict how an individual's exposure would change following a reorganisation of work. Using the above example, if the employee were to spend 15 extra minutes at 95dB the individual performing this work would now be exposed to an extra 32 points. This would increase the total exposure points to 149 + 32 = 181. This would take the total above the ELV of 160 points and thus means of reducing the individual's daily noise exposure would be required.

GUIDANCE NOTES ON UNDERTAKING A NOISE RISK ASSESSMENT USING THE 'EXPOSURE POINTS' SYSTEM

References:

A. Controlling Noise At Work, The Control of Noise at Work Regulations 2005. Guidance Document L108. ISBN 0-7176-6164-4. Health and Safety Executive 2005.
B. Statutory Instrument 2005 No 1643. The Control Of Noise At Work Regulations 2005.

a. At Reference A, the Health and Safety Executive define a detailed and systematic approach to the management of noise risks, covering risk assessment, planning how to control risks and putting the plan into action. This document describes the minimum adequate record required.

2. The major findings from the risk assessment and action plan must be recorded. The following sections are a logical way of dividing up the noise risk assessment and ensuring all necessary areas are covered.

a. **The name of the person(s) responsible for making the risk assessment.** To carry out the tasks involved in managing noise risks requires competence in particular areas, where these skills and knowledge are not available in-house you should call in external assistance, such as consultants, to carry out the work.

b. **The date(s) that the assessment was made.** You must review the risk assessment if there is any reason to think that it does not reflect the current noise risk in your workplace. For example:

(1) There are improved noise control techniques available.

(2) You need to determine the impact of new noise control measures.

(3) There is evidence of hearing damage.

It is therefore necessary to know the date(s) that the original assessment(s) were made.

c. **The workplaces, areas, jobs or people included in the assessment, including a description of the work going on.**

(1) If there is deemed to be a problem you must identify which employees are likely to be affected by the noise and how. All employees at risk need to be identified, for example not just those operating the machinery, but others working nearby, (as well as visitors and subcontractors). It is also important to consider people who move between different jobs or types of work during the day to understand their pattern of noise exposure.

(2) You need to determine whether the noise to which your employees are exposed may lead to risks in their health and safety. This can be done simply using the Noise Hazard Checklist (at Reference A) or the following listening checks:

(a) Are employees exposed to noise which makes it necessary to shout to talk to someone 1m away, for more than about half an hour per day in total?

(b) Are employees exposed to noise which makes it necessary to shout to talk to someone 2m away, for more than about 2 hours per day in total?

(c) Is conversation at 2m possible, but noise is intrusive – comparable to a busy street, a typical vacuum cleaner or a crowded restaurant – for more than about 6 hours per day in total?

(3) If 'yes' can be answered to any of these then you probably have risks that need managing. You can also use noise information provided by machinery manufacturers if applicable.

d. **If noise measurements have been made, relevant details of the measurements, including the person(s) responsible for carrying them out.** This includes the information used to determine noise exposure (Section E), the daily personal noise exposure (Section F) and the peak noise exposure levels (Section G). In this case, this NVDiv report can be referenced to cover the details of Sections D, E and G.

e. **The information used to determine noise exposure.**

(1) To evaluate the risks from noise you need to assess the noise exposure of your employees, in terms of daily or weekly personal noise exposure and exposure to peak noise. This requires information on the average noise level (L_{Aeq}) to which the worker is exposed during the tasks which make up the working day, and the duration of exposure. Maximum daily and weekly exposure time is provided in the report.

(2) Noise exposure can be easily assessed in situations where exposures are irregular, where workers intermittently use a variety of different machines, or spend time in different areas, by using the exposure points per set amount of time. These can be found in the report, and are calculated using the following formula:

$$EP_{15} = T.10^{\left[\frac{L_{Aeq}-109.6}{10}\right]}$$

EP_{15} is the number of exposure points per set amount of time
T is 900 seconds (15 minutes)
L_{Aeq} is the A weighted equivalent continuous noise level for the worst case at each position

(3) The LEAV, UEAV and ELV can be used to determine your legal duties under the Noise Regulations (Reference B). You can then evaluate whether risks from noise exposure are reduced to the lowest level reasonably practicable. This can be achieved by making sure you understand why the risks are low, so you are better able to make sure they remain that way, and to know when changes in the workplace could lead to increased risks.

(4) It should be noted that if you exceed the ELV at any point you must take immediate action. If the ELV is exceeded, even taking account of the hearing protection, then you should reduce exposure immediately, even if that means stopping the work.

f. **The daily personal noise exposures of the employees or groups of employees concerned.** The total number of exposure points acquired through out the day can then be calculated for each individual worker, and compared to the Lower Exposure Action Value (LEAV) of 32 points, the Upper Exposure Action Value (UEAV) of 100 points, and the Exposure Limit Value (ELV) of 160 points. See Annex A for further information.

g. **The peak noise exposure levels of the employees or groups of employees concerned.** This is more complicated and should ideally be done by specialist noise assessors with the relevant equipment. For impulsive noise the data is provided in this report.

h. **Any further information used to evaluate the risks.** The risks of noise exposure that need to be considered not only include hearing damage (deafness, tinnitus or other hearing problems), but risks to safety such as noise interfering with communications, warning signals and audible signs of danger. It is also important to take into account employees with pre-existing hearing conditions, those with a family history of deafness, pregnant women and young people.

i. **Your action plan to control noise risks.**

(1) It is important to remember your general duties to control noise risks, for example by considering alternative processes, equipment and/or working methods which would make the work quieter or mean people are exposed for shorter times. You should also identify where replacement or maintenance of tools could reduce exposure levels. PPE is used as a last resort. The Control of Noise Exposures – Good Practice and Industry Standards can be found at Reference A.

(2) The final stage in carrying out a noise risk assessment requires you to develop an action plan for investigating and introducing noise-control and risk-reduction measures, and any other measures required by the noise regulations. You should record both what you have done and what you intend to do. A detailed action plan can be found at Reference A.

MEASUREMENT EQUIPMENT USED DURING THE SURVEY

Table 1 - A List of Measurement Equipment Calibrators used.

Type	Model	Serial Number	Date of Last Calibration
Edirol Solid State Recorder	Roland R-09HR	22	n/a
		32	n/a
		34	n/a
		37	n/a

Type	Model	Serial Number	Date of Last Calibration
Acoustic Calibrator	B&K 4231	2431912	10 May 2012
		1771097	01 Sept 2011

Type	Model	Serial Number	Date of Last Calibration
Miniature Microphone sets	Knowles 1785	n/a	n/a

GLOSSARY OF TERMS

A-weighting	Weighting of the audible frequencies designed to reflect the response of the human ear to noise. The ear is more sensitive to noise at frequencies in the middle of the audible range than it is to either very high or very low frequencies. Noise measurements are often A-weighted (using a dedicated filter) to compensate for the sensitivity of the ear.
Attenuation	Noise reduction.
Calibrator	A device that produces a known sound pressure level at a known frequency. It may have controls to allow a range of sound pressure levels and frequencies to be produced.
Decibel (dB)	The units of sound measurement and noise exposure measurement.
dB(A)	Decibels A-weighted.
Impulsive noise	Any type of single or repeated noise of short duration, e.g. the noise from an explosion or the noise of a power press.
Insertion Loss	Reduction in noise level introduced by the use of a noise control device.
L_{Aeq}	A-weighted equivalent continuous sound pressure level. An average sound pressure level over a period of time.
$L_{A,max}$	Maximum Sound Pressure level - Maximum value of the A-weighted sound pressure level, measured in dB(A).
$L_{EP,d}$	Daily personal noise exposure - An individual's noise exposure normalised to an 8-hour working day.
$L_{EP,w}$	Weekly personal noise exposure - An individual's noise exposure normalised to a 40-hour working week.
$L_{eq,t}$	Equivalent continuous sound pressure level - A measure of the average sound pressure level during a period of time, t, in dB.
L_{Cpk}	Peak Sound Pressure Level - The maximum value reached by the sound pressure level at any instant during a measurement period (in dB, with C frequency weighting).
Loudness	The measure of the subjective impression of the magnitude or strength of a sound.
Noise exposure	A measure of the total sound energy a person is exposed to. It is dependent on both the sound pressure level to which the person is exposed and the time over which the exposure occurs.
NIHL	Noise Induced Hearing Loss.

Noise Exposure	A measure of the total sound energy a person is exposed to. It is dependent on both the sound pressure level to which the person is exposed and the time over which the exposure occurs.
Signal to Noise Ratio (SNR)	The difference between a communication signal and all other background sounds, expressed in decibels.
Sound pressure level (SPL)	The basic measure of noise loudness, expressed in decibels, usually measured with an appropriate frequency weighting (e.g. the A-weighted SPL in dB(A)).
UKAS	United Kingdom Accreditation Services.

MEASURED DATA ACQUIRED DURING PUMA HC2 ASSESSMENT SORTIES

Table 1 - Measured Data Acquired during Puma HC2 Assessment Sorties for Aircrew Wearing Various Helmets.

Sortie Number	Helmet	Position	Measured Cabin L_{Aeq} (dB)	Calculated At-ear L_{Aeq} (dB)	Measurement Duration (hh:mm:ss)
1	Mk 4A4 with CEP	Left Hand Pilot	FAIL*	FAIL*	FAIL*
2	Alpha 928 with CEP	Left Hand Pilot	FAIL*	FAIL*	FAIL*
1	Alpha with CEP	Right Hand Pilot	95.4	88.6	02:00:00
2	Mk4A4 with CEP	Right Hand Pilot	94.5	84.3	01:30:00
1	Mk 4A4 Only	Jump Seat	98.4	97.9	02:00:00
2	Mk 15 Passenger	Jump Seat	99.5	88.9**	01:30:00
1	Mk 4A4 with CEP	Cabin	104.2	91.2	02:00:00
2	Alpha 928 with CEP	Cabin	106.0	94.9	01:30:00

*Failed measurements for the Left Hand Pilot position are due to measuring equipment malfunction.

** Measured At-Ear noise level.

EMPLOYERS ACTIONS UNDER THE CONTROL OF NOISE AT WORK REGULATIONS

The Control of Noise at Work Regulations 2005 state: "*If any employee is likely to be exposed to noise at or above an upper exposure action value, the employer shall reduce risk to a minimum by establishing and implementing a programme of organisational and technical measures, excluding the provision of personal hearing protectors, which is appropriate to the activity and consistent with the risk assessment, and shall include consideration of:*

a. Other working methods which eliminate or reduce exposure to noise.

b. Choice of appropriate work equipment emitting the least possible noise, taking account of the work to be done.

c. The design and layout of workplaces, work stations and rest facilities.

d. Suitable and sufficient information and training for employees, such that work equipment may be used correctly, in order to minimise their exposure to noise.

e. Reduction of noise by technical means including:

(1) In the case of airborne noise the use of shields, enclosures and sound absorbent coverings; and

(2) In the case of structure-borne noise by damping and isolation.

f. Appropriate maintenance programmes for work equipment, the workplace and workplace systems.

g. Limitation of the duration and intensity of exposure to noise; and

h. Appropriate work schedules with adequate rest periods."

REPORT SUMMARY

Reference:

A. Programme Level Survey Protocol for Measurement of Exposure of personnel to Noise and Whole Body Vibration Incurred as a Result of UK Military Aircraft Activities, Version 3, DE&S ASEG, dated 27 Jul 07.

1. A summary of the attached report is presented here in accordance with Reference A.

a. **Aircraft/Vehicle Variants Covered**: Puma HC2 Aircraft.

b. **Positions Covered**: Right Hand Pilot (RHP), Jump Seat (JS) and Cabin.

c. **Helmets Covered**: Mk4, Alpha 928 and Mk15

d. **Activities Covered**: Representative Sorties

Table 1 – Allowable Exposure Time Limits When Wearing Mk 4A4 Helmet and CEP

Position	Calculated LAeq/dB	LEAV (hh:mm)		UEAV (hh:mm)		ELV (hh:mm)		Exposure Points per 15 Minutes
		Daily	Weekly	Daily	Weekly	Daily	Weekly	
RHP	85	02:31	12:38	08:00	40:00	12:40	63:23	3.1
JS	86	02:00	10:02	06:21	31:46	10:04	50:21	3.9
Cabin	92	00:30	02:31	01:35	07:58	02:31	12:38	15.6

Table 2 – Allowable Exposure Time Limits When Wearing Alpha 928 Helmet and CEP

Position	Calculated LAeq/dB	LEAV (hh:mm)		UEAV (hh:mm)		ELV (hh:mm)		Exposure Points per 15 Minutes
		Daily	Weekly	Daily	Weekly	Daily	Weekly	
RHP	89	01:00	05:02	03:11	15:55	05:02	25:14	7.8
JS	90	00:48	04:00	02:31	12:38	04:00	20:02	9.9
Cabin	95	00:15	01:15	00:48	04:00	01:16	06:20	31.2

Table 3 – Allowable Exposure Time Limits When Wearing Mk 15 Passenger Helmet and occupying the JS position

Position	Masured LAeq/dB	LEAV (hh:mm)		UEAV (hh:mm)		ELV (hh:mm)		Exposure Points per 15 minutes
		Daily	Weekly	Daily	Weekly	Daily	Weekly	
JS	89	01:00	05:02	03:11	15:55	05:02	25:14	7.8

RECOMMENDATIONS

a. As a result of this survey, it is recommended that:

   a. A good fit of headset needs to be ensured.

   b. Aircrew should be informed that they are at risk of NIHL and be instructed to use the minimum feasible volume of communications.

   c. The MOD standard CEP is adopted.

   d. Modify the communications system to enable independent volume control.

b. The aircrew should be given information on the causes and effects of NIHL and how to minimise the risks in their working environment. This should include instruction to:

   a. Use only the very minimum volume level they require to understand the messages over background noise (SNR), adjusting the volume control according to the attenuated background noise especially during engine start and taxi

   b. To listen to only those channels it is necessary for them to listen to.

   c. To only monitor the communications channels when it is necessary to do so.

c. It is recommended that further consideration is given to:

   a. Fitment of warning lights to both consoles to make the aircrew aware that excessive SNR levels are being used.

   b. Modification to the communications system to include filters to improve the quality of the audio and minimise the unnecessary frequencies to which aircrew members are exposed.

   c. Carrying out further assessments including additional airframes to increase the sample size of the data collected and improve the reliability of results.

d. It is accepted that during operational scenarios it may be necessary to use otherwise undesirably high SNR during some activities. For this reason it is not suggested that the communications system be fitted with limiters. However, the implementation of a warning light on each console, activated by the use of SNR above 15dB, is recommended. This would allow the aircrew to be aware that undesirable levels were being used and levels should be reduced during routine or training sorties. Some consideration of an Automatic Gain Control (AGC) mechanism should be undertaken, but any AGC system should similarly have an override in order to allow higher SNR use when necessary.

e. The communications system fitted to each of the aircraft should be tested and maintained/repaired if necessary. The implementation of electronic filters into the communications system should be considered to improve the quality of the audio. As an example, a 'bandpass' filter specific to voice communication frequencies necessary to prevent loss of speech intelligibility (300Hz to 4000Hz), could be effective in reducing exposure to unnecessary signals and system noise. Quality of the reproduced signal should be a consideration when any upgrades to the communications system are undertaken.

OCCUPATIONAL AND ENVIRONMENTAL MEDICINE WING

NOISE AND VIBRATION DIVISION

Report: OEM/51/08 Dated September 2008

A REPORT ON AN INFLIGHT NOISE ASSESSMENT OF TRISTAR AIRCRAFT CREW DURING REPRESENTATIVE SORTIES AT RAF BRIZE NORTON

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Date

CONDITIONS OF RELEASE

OCCUPATIONAL AND ENVIRONMENTAL MEDICINE WING
NOISE AND VIBRATION DIVISION

ROYAL AIR FORCE CENTRE OF AVIATION MEDICINE

Report No: OEM/51/08

A REPORT ON AN INFLIGHT NOISE ASSESSMENT OF TRISTAR AIRCRAFT CREW DURING REPRESENTATIVE SORTIES AT RAF BRIZE NORTON

EXECUTIVE SUMMARY

1. The Noise and Vibration Division (NVDiv) of the RAF Centre of Aviation Medicine was tasked by the Integrated Project Team (IPT) Leader of the Air Refuelling and Communication IPT (ARC IPT) to perform a noise exposure survey of personnel inflight during sorties on board the TriStar K1, KC1 and C2 aircraft, at RAF Brize Norton. The work undertaken by the NVDiv was performed under the purview of a tasking instigated by Eng Pol AW and SHEF covering all aircraft types and variants in the MOD Fleet, prompted by the implementation of the Control of Noise at Work Regulations 2005.

2. The TriStar is a wide-body multi-engined aircraft manufactured by Lockheed and capable of carrying large loads over considerable distances. The TriStar variants covered by this report are the K1 and KC1 – used as both tankers and cargo/passenger transports, and the C2 – a passenger aircraft.

3. The noise assessment was carried out for the TriStar aircrew and passengers during circuit training, refuelling and passenger transport sorties. These flights were performed between Jul 07 and Feb 08.

4. The introduction of the UK Noise Regulations has the potential to limit the operating time for TriStar crews unless steps are taken to mitigate the hazards. An earlier assessment, reported in Mar 01, examined the noise exposure of TriStar cabin crew, but following the implementation of the new legislation, a further survey was requested.

5. The levels of aircrew noise exposure are calculated for the worst case at-ear noise, broken down by position. This has been done as the legislation which drives this noise survey requires assessments to be person specific, rather than job specific. This is to take into account individual factors including the fit of hearing protection.

6. Table 1 shows the daily and weekly exposure times, based on the worst case measured at-ear noise levels, for the different personnel and worst case seating on board the C2, K1 and KC1 TriStar variants.

Table 1 – Daily and Weekly Exposure Times for Monitored Personnel and Worst Case Seating Onboard C2, K1 and KC1 TriStar Variants

Variant	Personnel	Time Until LEAV Exceeded (Risking NIHL)/(HH:MM)		Time Until ELV Exceeded (Absolute Limit)/(HH:MM)	
		Daily	Weekly	Daily	Weekly
C2	Stewards	02:31	12:38	12:40	63:23
	Cockpit crew	01:16	06:20	06:21	31:46
	Loadmasters	05:02	25:14	25:17	126:29
	Seat 30B	04:00	20:02	20:05	100:28
K1	Cockpit crew	01:35	07:58	08:00	40:00
	Loadmasters	02:00	10:02	10:04	50:21
	Seats 20C and 21A	01:35	07:58	08:00	40:00
KC1	Stewards	01:16	06:20	06:21	31:46
	Cockpit crew	00:38	03:10	03:11	15:55
	Loadmasters	02:00	10:02	10:04	50:21
	Seat 27A	00:38	03:10	03:11	15:55

7. It is recommended that:

a. If possible, sortie times should be kept within the limits proposed above. Where it is not possible to keep to daily action values or limits, weekly exposure limits should be considered.

b. Stewards, loadmasters and passengers should be encouraged to wear the hearing protection provided to them, particularly on board the KC1 variant, and towards the rear of the aircraft.

c. Although in some cases this method already seems to be practiced, it may be a good idea to rotate the areas of the aircraft in which crew are working throughout the flight. For example, a steward working at the rear galley may switch places with one towards the front of the craft for the second half of the sortie, in order to distribute the exposure more evenly between individuals.

d. If possible, passengers could be seated further forward in the aircraft, rather than towards the noisier rear. If the plane is operating below full capacity, for example, the seats at the rear could be left empty altogether.

e. Cockpit crew should be encouraged to reduce communications volume to the minimum level necessary. Cockpit crew should also be encouraged to keep the door to the cabin closed in order to reduce the ambient noise in the cockpit.

f. The communications system should be checked, and, if possible, the continual noise put out when there is no useful transmission coming through should be reduced or eliminated.

g. All aircraft crew should be advised on the causes and effects of Noise Induced Hearing Loss and how to minimise the risks in their working environment.

8. Further consideration is recommended to:

a. Installation of warning lights to each console to make both the crewmember and aircraft captain aware that excessive Signal to Noise Ratio levels are being used.

b. Modification to the communications system to include bandpass filters to improve the quality of the audio and minimise the unnecessary frequencies to which aircrew and passengers are exposed.

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CONTENTS

SECTION	PAGES
Introduction	1
Background	1
Relevant Standards	2
Measurement Procedure	2
Analysis	4
Results	5
Discussion	7
Conclusion	10
Recommendations	10
Acknowledgements	11

ANNEXES

A.	The 'Exposure Points' System For Assessing Noise Exposure.	A-1
B.	List Of Equipment Used During The Survey.	B-1
C.	Noise Exposure Data For C2 Aircraft Crew.	C-1
D.	Noise Exposure Data For K1 Aircraft Crew.	D-1
E.	Noise Exposure Data For KC1 Aircraft Crew.	E-1
F.	Passenger Seating Noise Maps.	F-1
G.	Report Summary.	G-1

OCCUPATIONAL AND ENVIRONMENTAL MEDICINE WING

NOISE AND VIBRATION DIVISION

ROYAL AIR FORCE CENTRE OF AVIATION MEDICINE

Report No: OEM/51/08

A REPORT ON AN INFLIGHT NOISE ASSESSMENT OF TRISTAR AIRCRAFT CREW DURING REPRESENTATIVE SORTIES AT RAF BRIZE NORTON

Authors: [redacted]

REFERENCES

A. RAF CAM Tasking Proforma CAM/224/05/07/NVD dated 17 Jun 04.
B. Statutory Instrument 2005 No 1643. The Control of Noise at Work Regulations 2005.
C. A Report on a Noise Assessment of the TriStar Aircraft Non-Flight Deck Crew. RAF CAM Report Number OEM/10/01 dated Mar 01.
D. Defence Instructions and Notices 2006DIN07-008. MOD Policy for the Control of Noise and Vibration at Work Regulations 2005.

INTRODUCTION

1. The Noise and Vibration Division (NVDiv) of the RAF Centre of Aviation Medicine (RAF CAM) was tasked at Reference A by the Integrated Project Team (IPT) Leader of the Air Refuelling and Communication IPT (ARC IPT) to perform a noise exposure survey of personnel inflight during sorties on board the TriStar K1, KC1 and C2 aircraft. The work undertaken by the NVDiv was performed under the purview of a tasking instigated by Eng Pol AW and SHEF covering all aircraft types and variants in the MOD Fleet, prompted by the implementation of the Control of Noise at Work Regulations 2005 (Reference B).

2. An earlier assessment of TriStar cabin crew noise (Reference C) recommended that cabin crew be encouraged to wear low-attenuation ear-plugs, to reduce noise exposure, whilst still allowing easy communication. However, during our survey this advice did not seem to be widely followed.

3. The noise assessment was carried out for the TriStar aircrew and passengers during refuelling, training and passenger transport sorties. These flights were performed between Jul 07 and Feb 08.

BACKGROUND

4. The introduction of the UK Noise Regulations at Reference B has the potential to limit the operating time for TriStar crews unless steps are taken to mitigate the hazards. An earlier assessment, reported at Reference C, examined the noise exposure of TriStar cabin crew, but following the implementation of the new legislation, a further survey was requested.

5. The TriStar is a wide-body multi-engined aircraft manufactured by Lockheed and capable of carrying large loads over considerable distances. The TriStar variants covered by this report are; the K1 and KC1 – used as both tankers and cargo/passenger transports, and the C2 – a passenger aircraft.

6. The cockpit crew were wearing Senheiser HME 1410KA headsets, but no hearing protection was worn by any of the aircrew.

RELEVANT STANDARDS

7. MOD policy on noise at work is based upon Reference B and is defined at Reference D. References B and D define action and limit values for daily exposure to noise normalised to an 8-hour working day. They define a Lower Exposure Action Value (LEAV) for continuous noise at an $L_{EP,d}$ of 80dB(A), an Upper Exposure Action Value (UEAV) for continuous noise at an $L_{EP,d}$ of 85dB(A) and an Exposure Limit Value (ELV) at an $L_{EP,d}$ of 87dB(A). The use of a weekly noise exposure level ($L_{EP,w}$) is also defined, normalised to a 5-day, 40 hour working week.

8. The Regulations also define action and limit values for impulsive (peak) noise. It is unlikely that the aircrew on board the TriStar will be exposed to any excessive impulsive (peak) noise during their normal sorties, therefore only the continuous noise and its relevant standards will be considered here.

9. For both continuous and impulsive noise, the ELV includes the effect of hearing protection. The ELV of 87dB(A) cannot be exceeded legally unless an exemption certificate is granted. The platform IPT Leader is responsible for this and must submit a safety case to the Secretary of State for Defence to obtain the exemption. The procedure for obtaining an exemption is defined at Reference D. An exemption will only be granted if it can be demonstrated that noise exposure has been reduced to as low a level as is reasonably practicable.

9. The standard unit of noise level measurement is the decibel. To make an understanding of noise dosage easier for employers and employees, the Health and Safety Executive (HSE) has introduced a points system whereby the noise levels experienced are allocated a certain number of points. When performing a number of duties with different noise levels and durations, the cumulative noise dose can be calculated by summing the exposure points for each task to obtain a total exposure point value. This value can be compared to the various action and limit values to determine risk. The HSE set the LEAV at 32 points, the UEAV at 100 points and the ELV at 160 points. Further information and a worked example of the exposure points system can be found at Annex A.

MEASUREMENT PROCEDURE

10. Measurements were made on board a variety of sorties flown between Jul 07 and Feb 08. Details of these sorties are given in Table 1.

Table 1 – Sortie Details

Sortie Number	Date	Sortie	Variant	Airframe	Individuals/Areas Assessed
1	4-Jul-07	AAR (RAF Brize Norton)	K1	ZD949	Engineer, LH pilot, RH pilot, loadmaster, passenger seating
2	16-Oct-07	RAF Brize Norton - Munich	KC1	ZD950	Engineer, LH pilot, RH pilot
3	6-Dec-07	AAR (RAF Brize Norton)	KC1	ZD950	Engineer, LH pilot, RH pilot, crew seating, passenger seating
4	13-Dec-07	AAR (RAF Brize Norton)	KC1	ZD950	Air steward (front), engineer, loadmaster, LH pilot, RH pilot, crew seating, passenger seating
5	17-Jan-08	MCT (RAF Brize Norton)	KC1	ZD948	Air steward, engineer, instructor, loadmaster, LH pilot, RH pilot, passenger seating
6	22-Jan-08	RAF Brize Norton - RAF Akrotiri	KC1	ZD948	Air stewards (front, middle and rear), engineer, LH pilot, RH pilot, crew seating, passenger seating
7	23-Jan-08	RAF Akrotiri - RAF Brize Norton	KC1	ZD948	Air stewards (front, middle and rear), engineer, LH pilot, RH pilot, crew seating, passenger seating
8	14-Feb-08	RAFO Seeb - RAF Brize Norton	C2	ZE704	Air stewards (middle and rear), engineer, loadmaster, LH pilot, RH pilot, crew seating, passenger seating
9	21-Feb-08	RAFO Seeb - RAF Akrotiri	C2	ZE706	Air stewards (middle and rear), engineer, loadmaster, LH pilot, RH pilot, crew seating, passenger seating
10	21-Feb-08	RAF Akrotiri - RAF Brize Norton	C2	ZE706	Air stewards (middle and rear), engineer, loadmaster, LH pilot, RH pilot, crew seating, passenger seating

11. When monitoring the exposure of cockpit crew a Knowles BL-21785 miniature microphone was fitted just inside the outer-ear, using surgical tape, to measure at-ear noise throughout. A second was inserted into a wind-guard and attached to the shoulder of the individual's flight suit in order to monitor the ambient noise in the cockpit. The output from the microphones was fed into an Edirol R-09 solid-state recorder, allowing the signal to be recorded for analysis.

12. When monitoring the exposure of cabin crew (stewards and loadmasters) both microphones, inside wind guards, were fixed to the shoulders to record cabin noise data.

13. On sorties 4, 5, 6 and 7 passenger and crew seating and working area measurements were taken in a similar manner, with the equipment fitted to a NVDiv team member who moved between seats and areas of the aircraft taking ambient noise measurements of around 90 seconds in each position.

14. On sorties 3, 8, 9 and 10, however, passenger and crew seating and working area recordings were made using a 01dB Opus unit. The Opus is a 2-channel battery operated microphone power supply. The Opus is used in connection with an Edirol and a Brüel and Kjær (B&K) Type 4190 half-inch microphone.

15. All noise monitoring equipment was calibrated both before and after measurements, where possible, using a B&K Type 4231 Acoustic Calibrator which produces a reference tone of 94dB at a frequency of 1kHz and is traceable to and comparable with, a UKAS reference standard.

16. Annex B contains details of all equipment used during the surveys.

ANALYSIS

17. The aircrew recordings were downloaded and processed in 01dB dBFA – a software signal processing suite. Using 01dB dBFA, signal analysis was performed on the recorded files, producing data compatible with 01dB dBTrait software.

18. In 01dB dBTrait the calibration data were examined and the flight data were adjusted by an appropriate calibration value. In keeping with the exposure criteria, the period from engine start-up to shut-down was identified in each recording and, across these regions, values for L_{Aeq} were extracted.

19. The sortie durations often exceeded the maximum storage capability of the digital medium in use. It was therefore necessary to compile results from a number of recordings in order to calculate the overall exposure recorded during the sortie.

20. Values for Signal-to-Noise Ratio (SNR) used by the cockpit crew were found by analyzing adjacent parts of the signal with and without evident communications usage. The SNR is then determined by calculating the dB difference between the signal with communications and the signal without.

21. The passenger area recordings were processed and calibrated in the same manner as the aircrew recordings and then the ambient portions of the signal (i.e. those without observable speech or other fluctuations) were analysed and L_{Aeq} values were extracted.

22. The L_{Aeq} values were used to calculate the period of time each working day that a crewmember can fly, up to an $L_{EP,d}$ (measure of the average noise exposure that a person is exposed to during a working day, based on an 8 hour day) noise exposure equivalent to the action and limit values defined at References B and D. From these, values for exposure points per 5 minutes were calculated.

23. The legislation also allows the full working week to be taken into account. As it is unlikely that each pilot will fly daily, calculations of exposure time limits based on $L_{EP,w}$ (measure of the average noise exposure that a person is exposed to during a working week, based on 5 working days of 8 working hours) will increase the allowable flight time per week. Calculations have been performed, based on the measured levels, to ascertain how many flying hours each crewmember can fly within the space of one 40-hour 5-day week before reaching the exposure action and limit values defined at References B and D.

24. The noise exposure levels to which TriStar pilots can be exposed and time limits which they can fly daily or weekly were calculated, based on the assumption that they spend the rest of the working day or week in a quiet environment (less than 70dB(A) at-ear).

RESULTS

25. Annexes C, D and E contain noise exposure data for the aircrew monitored on board the C2, K1 and KC1 variants respectively. Annex F contains numerical worst case noise maps of the passenger seating areas of the C2, K1 and KC1 variants.

26. For the purposes of this report, personnel on board the TriStar aircraft were organised into 4 groups. These groups were:

a. Cockpit crew (Pilots and Engineers).

b. Loadmaster.

c. Stewards.

d. Passengers.

27. For personnel that routinely wear headsets (usually only cockpit crew), reported results are from at-ear measurements which will include the contribution from any communications signals. For all other personnel, the reported results are ambient noise levels measured from shoulder mounted microphones.

28. Table 2 contains the worst case at-ear noise levels measured for cockpit crew, loadmasters and stewards during all the flights on the C2 variant. Table 2 also contains maximum daily and weekly exposure times calculated from these noise levels. Tables 3 and 4 contain the same data for the K1 and KC1 variants respectively.

Table 2 – Worst Case Noise Levels and Maximum Daily and Weekly Exposure Times for C2 Variant Aircrew

		Maximum Exposure Times (HH:MM)					
Crew	**Worst Case L_{eq} (dB(A))**	**LEAV**		**UEAV**		**ELV**	
		Daily	Weekly	Daily	Weekly	Daily	Weekly
Cockpit	88	01:16	06:20	04:00	20:02	06:21	31:46
Loadmaster	82	05:02	25:14	15:57	79:48	25:17	126:29
Stewards	85	02:31	12:38	08:00	40:00	12:40	63:23

Table 3 – Worst Case Noise Levels and Maximum Daily and Weekly Exposure Times for K1 Variant Aircrew

		Maximum Exposure Times (HH:MM)					
Crew	**Worst Case L_{eq} (dB(A))**	**LEAV**		**UEAV**		**ELV**	
		Daily	Weekly	Daily	Weekly	Daily	Weekly
Cockpit	87	01:35	07:58	05:02	25:14	08:00	40:00
Loadmaster	86	02:00	10:02	06:21	31:46	10:04	50:21
Stewards*	-	-	-	-	-	-	-

* No stewards were present onboard the K1 variant during measurements.

Table 4 – Worst Case Noise Levels and Maximum Daily and Weekly Exposure Times for KC1 Variant Aircrew

Crew	Worst Case L_{eq} (dB(A))	Maximum Exposure Times (HH:MM)					
		LEAV		UEAV		ELV	
		Daily	Weekly	Daily	Weekly	Daily	Weekly
Cockpit	91	00:38	03:10	02:00	10:02	03:11	15:55
Loadmaster	86	02:00	10:02	06:21	31:46	10:04	50:21
Stewards	88	01:16	06:20	04:00	20:02	06:21	31:46

29. Table 5 contains the number of exposure points that would be received from 5-minutes exposure to the noise levels detailed in Tables 2, 3 and 4. Table 6 contains the worst case and typical SNR values for each variant.

Table 5 – Exposure Points per 5 Minutes Calculated from Worst Case At-ear Noise Levels for Aircrew on all Variants

Crew	Exposure Points per 5 Minutes		
	C2	K1	KC1
Cockpit	2.1	1.6	4.1
Loadmaster	0.5	1.3	1.3
Stewards*	1.0	-	2.1

* No stewards were present onboard the K1 variant during measurements.

Table 6 – Worst Case and Typical SNR Values

Variant	SNR (dB)	
	Worst Case	Typical
C2	15	11
K1	19	12
KC1	12	9

30. Table 7 contains the worst case and typical noise level for all passenger seating on board the C2 variant. Where a crew working area (such as a galley) is equal to or louder than a particular seat, then this is also mentioned. Table 7 also contains the maximum daily and weekly exposure times calculated from these noise levels. Table 7 also contains the number of exposure points that would be received from exposure to these noise levels for 5-minutes. Tables 8 and 9 contain this data for the K1 and KC1 variants respectively.

Table 7 – Worst Case and Typical C2 Passenger Seating and Crew Working Area Values

Seat/Area		L_{Aeq} (dB(A))	Maximum Daily Exposure Times (HH:MM)						Exposure Points per 5 Minutes
			LEAV		UEAV		ELV		
			Daily	Weekly	Daily	Weekly	Daily	Weekly	
Worst Case	Rear galley and Seat 30B	83	04:00	20:02	12:40	63:23	20:05	100:28	0.7
Typical	-	77	15:57	79:48	U/R*	U/R*	U/R*	U/R*	0.2

*Unreachable during any 24-hour or 7-day period respectively.

Table 8 – Worst Case and Typical K1 Passenger Seating and Crew Working Area Values

Seat/Area		L_{Aeq} (dB(A))	Maximum Daily Exposure Times (HH:MM)						Exposure Points per 5 Minutes
			LEAV		UEAV		ELV		
			Daily	Weekly	Daily	Weekly	Daily	Weekly	
Worst Case	20C and 21A	87	01:35	07:58	05:02	25:14	08:00	40:00	1.6
Typical	-	79	10:04	50:21	U/R*	U/R*	U/R*	U/R*	0.3

*Unreachable during any 24-hour or 7-day period respectively.

Table 9 – Worst Case and Typical KC1 Passenger Seating and Crew Working Area Values

Seat/Area		L_{Aeq} (dB(A))	Maximum Daily Exposure Times (HH:MM)						Exposure Points per 5 Minutes
			LEAV		UEAV		ELV		
			Daily	Weekly	Daily	Weekly	Daily	Weekly	
Worst Case	27A	91	00:38	03:10	02:00	10:02	03:11	15:55	4.1
Typical	-	82	05:02	25:14	15:57	79:48	U/R*	126:29	0.5

*Unreachable during any 24-hour or 7-day period respectively.

31. A technical summary can be found at Annex G.

DISCUSSION

32. Reference C reports on a noise survey performed on cabin crew on board TriStar aircraft. Ambient noise measurements were made in the areas where cabin crew work for the majority of each flight. It was recommended that if other means of reducing noise at the rear of the cabin are not found then the provision of suitable low-attenuation hearing protection should be investigated.

33. It should also be noted that only one sortie was available for monitoring on board the K1 variant. Therefore, the quantity of data collected was far smaller and the results may be considered less conclusive due to this reduced sample size.

34. The levels of aircrew noise exposure are calculated for the worst case, based upon the crewmember having the highest at-ear noise dose recorded during all flights broken down by variant. This has been done as the legislation which drives this noise survey requires assessments to be person specific, rather than job specific, to take into account individual factors.

35. The aircrew have been allocated into 3 groups for the purposes of this assessment; cockpit crew, stewards and loadmasters, in order to allow differentiation between the noise levels experienced by those fulfilling different roles on board the aircraft.

36. As the TriStar is also used for passenger transport, noise levels experienced by passengers situated in different areas of the aircraft have also been examined.

37. Aircrew should be given information on the causes and effects of Noise Induced Hearing Loss (NIHL) and how to minimise the risks in their working environment. For

cockpit crews, and any other crew who spend a significant proportion of the flight using a headset, this should include instruction to use only the very minimum SNR (volume level) required to understand the messages, to listen to only those channels it is necessary for them to monitor and to only monitor the communications channels when it is necessary to do so.

38. It should be noted that a SNR of 10dB is the generally accepted requirement for intelligible speech. Measured levels above an SNR of 10dB may be due to poor quality of the communications system, faint and garbled signals being deciphered and/or poor training of crew in terms of the use of the communications system.

39. It is accepted that during operational scenarios it may be necessary to use otherwise undesirably high SNR during some activities. For this reason it is not suggested that the communications system be fitted with limiters. However, the implementation of a warning light on each console, activated by the use of SNR above 10dB, is recommended. Such a system would need to be developed, as none are available commercially off the shelf. This would allow both the operator of the console and the aircraft captain to be aware that undesirable levels were being used and levels should be reduced during routine or training sorties.

40. High communications SNR levels can be a product of poor quality audio, such as high levels of static and feedback, or interference. The communications system fitted to each of the aircraft should be tested and repaired if necessary. The implementation of electronic filters into the communications system should be considered to improve the quality of the audio. Also a 'bandpass' filter specific to voice communication frequencies necessary to prevent loss of speech intelligibility (300Hz to 4000Hz), could be effective in reducing exposure to unnecessary signals and system noise. Ensuring the microphone system only operates when either spoken into or when selected using a manual switch would ensure that unnecessary broadcasting of cabin ambient noise would not take place. Quality of the reproduced signal should be a consideration when any upgrades to the communications system are undertaken.

41. Details of the SNR values found during the sorties monitored on board the TriStar can be found in Table 6 and at Annexes C, D and E. The worst case recorded value of 19.3dB(A) is in excess of the necessary communications volume. The SNR values in TriStar communications are higher than is preferable and steps should be taken to reduce these levels.

42. Further to this, the results suggest that there is an issue with the communications headsets being used on board the TriStar, which consistently causes the ear which receives communications to have greater noise exposure than the ear which does not, whether communications are being received or not. Although the level of this constant noise is not large, typically 2dB(A), it should be eliminated.

43. Stewards, loadmasters and passengers should be encouraged to wear appropriate hearing protection, particularly those spending long periods of time in the louder areas of the aircraft; the rear in particular.

44. The galley equipment – refrigerators, coolers, etc – represent a significant source of noise exposure for the air stewards in particular, and also for any passengers seated in

close proximity. At the rear of the aircraft, the centre engine also provides a significant noise source for both crew and passengers.

45. Technically the LEAV and UEAV can be exceeded; the requirement is for action to be taken (the ELV of 87dB(A) cannot be exceeded). Actions required by employers exceeding the LEAV and UEAV to protect employees are detailed in the legislation. The Control of Noise at Work Regulations 2005 state: "*If any employee is likely to be exposed to noise at or above an upper exposure action value, the employer shall reduce risk to a minimum by establishing and implementing a programme of organisational and technical measures, excluding the provision of personal hearing protectors, which is appropriate to the activity and consistent with the risk assessment, and shall include consideration of:*

(a) Other working methods which eliminate or reduce exposure to noise.

(b) Choice of appropriate work equipment emitting the least possible noise, taking account of the work to be done.

(c) The design and layout of workplaces, work stations and rest facilities.

(d) Suitable and sufficient information and training for employees, such that work equipment may be used correctly, in order to minimise their exposure to noise.

(e) Reduction of noise by technical means including:

(i) In the case of airborne noise the use of shields, enclosures and sound absorbent coverings; and

(ii) In the case of structure-borne noise by damping and isolation.

(f) Appropriate maintenance programmes for work equipment, the workplace and workplace systems.

(g) Limitation of the duration and intensity of exposure to noise; and

(h) Appropriate work schedules with adequate rest periods."

46. According to the legislation the employer shall only resort to the provision of hearing protection if the above measures are unsuccessful in reducing the noise levels to below the UEAV. If the ELV is exceeded the employer is duty-bound to reduce the exposure to below the limit value.

47. The 3-stage process of controlling excessive noise exposure of employees is defined at Reference B. This details the preferred order in which noise attenuating measures should be taken. It is stated that the noise should first be controlled at source, meaning steps should be undertaken to reduce the unwanted noise being generated from the process. The second stage is to control noise in the path between the source and employee, usually involving barriers, absorbent materials and separation of the source and employee. The third and least preferred stage involves issuing suitable Personal Protective Equipment (PPE) to employees exposed to noise.

48. Research has been conducted into volumetric Active Noise Cancellation (ANC) within aircraft fuselages using a matrix of microphones and speakers to produce destructive interference and reduce noise levels. This technology is in its infancy and may be prohibitively expensive to implement at present, but should again be incorporated into a programme of 'technology watching' for future aircraft upgrades. Again specialist companies are undertaking research into this approach and the NVDiv is available to advise the ARC IPT as subject matter experts.

49. Future modification to the aircraft (for example, additional external antennae (which produce aerodynamic noise), engine upgrades, and interior equipment upgrades, etc.) should take into account the potential impact on the noise exposure of personnel.

CONCLUSION

50. The noise to which cockpit crew, stewards, loadmasters and passengers are exposed is excessive in terms of References B and D, on board all TriStar variants, since routine sortie durations are greater than the daily exposure period necessary to put crew members at risk of NIHL. However, calculated on a weekly basis it may be possible to bring exposure levels down to an acceptable limit.

51. Exposure to noise in excess of the LEAV, UEAV and ELV will occur when aircrew are exposed over the times shown in Tables 2, 3 and 4 for the C1, K1 and KC1 variants respectively. Exposure over the LEAV will result in the risk of NIHL. Exposure over the UEAV will increase that risk. Exposure over the ELV is not permitted by References B and D.

52. For the worst case passenger seat on board the C2, seat 30B, a daily exposure time of over 4 hours puts the occupant at risk of NIHL. The ELV would be exceeded after 20 hours 5 minutes. Calculated weekly, these figures are 20 hours 2 minutes and 100 hours 28 minutes, respectively.

53. For the worst case passenger seating on board the K1, seats 20C and 21A, a daily exposure time of over 1 hour 35 minutes puts the occupant at risk of NIHL. The ELV would be exceeded after 8 hours. Calculated weekly, these figures are 7 hours 58 minutes and 40 hours, respectively.

54. For the worst case passenger seat on board the KC1, seat 27A, a daily exposure time of over 38 minutes puts the occupant at risk of NIHL. The ELV would be exceeded after 3 hours 11 minutes. Calculated weekly, these figures are 3 hours 10 minutes and 15 hours 55 minutes, respectively.

RECOMMENDATIONS

55. It is recommended that:

a. If possible, sortie times should be kept within the limits proposed in Tables 2, 3 and 4. Where it is not possible to keep to daily action values or limits, weekly exposure limits should be considered.

b. Stewards, loadmasters and passengers should be encouraged to wear the hearing protection provided to them, particularly on board the KC1 variant, and towards the back of the aircraft.

c. To equalise the exposure across loadmaster and steward personnel, rotation of the areas of the aircraft in which crew are working throughout the flight should be introduced. For example, a steward working at the rear galley may switch places with one towards the front of the aircraft for the second half of the sortie, in order to distribute the exposure more evenly between individuals.

d. If possible, passengers should be seated further forward in the aircraft, rather than towards the noisier rear. If the plane is operating below full capacity, for example, the seats at the rear could be left empty altogether.

e. Cockpit crew should be encouraged to reduce communications volume to the minimum level necessary. Cockpit crew should also be encouraged to keep the door to the cabin closed in order to reduce the ambient noise in the cockpit.

f. The communications system should be checked, and, if possible, the continuous noise emitted when there is no useful transmission coming through should be reduced or eliminated.

g. All aircraft crew should be advised on the causes and effects of NIHL and how to minimise the risks in their working environment.

56. Further consideration is recommended to:

a. Installation of warning lights to each console to make both the crewmember and aircraft captain aware that excessive SNR levels are being used.

b. Modification to the communications system to include bandpass filters to improve the quality of the audio and minimise the unnecessary frequencies to which aircrew are exposed.

ACKNOWLEDGEMENTS

57. Thanks to all 216 Sqn personnel for their assistance and cooperation, and to the relevant individuals at RAF Akrotiri and RAFO Seeb.

THE 'EXPOSURE POINTS' SYSTEM FOR ASSESSING NOISE EXPOSURE

Reference:

A. Health and Safety Executive. Controlling Noise at Work. The Control of Noise At Work Regulations 2005. L108. ISBN 0-7176-6164-4.

1. At Reference A, the Health and Safety Executive define an alternative system of noise exposure assessment. It is a simplified method of calculating an individual's noise exposure when they are exposed to a number of different sources. It is designed so that either the individual or the employer can assess and manage their own or their employees individual noise exposure.

2. Table 1 provides the means to calculate personnel's daily noise exposure based on level of noise and duration. It is suitable for both steady and variable noise exposure throughout the day. It allows noise exposure for individual jobs to be converted into points and totalled to find out the total daily exposure. This system will make apparent the jobs that contribute the greatest noise exposure to the total.

Table 1 – Noise Exposure Calculator

Sound Pressure Level, L_{Aeq} (dB)	Duration of exposure (hours)							
	1/4	1/2	1	2	4	8	10	12
105	320	625	1250					
100	100	200	400	800				
97	50	100	200	400	800			
95	32	65	125	250	500	1000		
94	25	50	100	200	400	800		
93	20	40	80	160	320	630		
92	16	32	65	125	250	500	625	
91	12	25	50	100	200	400	500	600
90	10	20	40	80	160	320	400	470
89	8	16	32	65	130	250	310	380
88	6	12	25	50	100	200	250	300
87	5	10	20	40	80	160	200	240
86	4	8	16	32	65	130	160	190
85		6	12	25	50	100	125	150
84		5	10	20	40	80	100	120
83		4	8	16	32	65	80	95
82			6	12	25	50	65	75
81			5	10	20	40	50	60
80			4	8	16	32	40	48
79				6	13	25	32	38
78				5	10	20	25	30
75					5	10	13	15

Table 2 – Points/Noise level converter

Total Exposure Points	Noise Exposure $L_{EP,d}$ (dB)
3200	100
1600	97
1000	95
800	94
630	93
500	92
400	91
320	90
250	89
200	88
160	87
130	86
100	85
80	84
65	83
50	82
40	81
32	80
25	79
20	78
16	77

3. In the noise exposure points scheme, the Lower Exposure Action Value (LEAV) is 32 points ($L_{EP,d}$ of 80dB), the Upper Exposure Action Value (UEAV) is 100 points ($L_{EP,d}$ of 85dB), and the Exposure Limit Value (ELV) is 160 points ($L_{EP,d}$ of 87dB).

4. Table 3 shows a worked example for calculating daily personal noise exposure. In the example, an employee is exposed to a noise level of 80dB for 5 hours; 2 hours at 86dB; 45 minutes at a noise level of 95dB.

Table 3 – Example of Calculating Daily Noise Points

Noise Level	Duration	Notes	Exposure Points
80	5 hrs	No column for 5 hours, so add together values from 4 and 1 hour columns in row corresponding to 80dB.	16 + 4 = 20
86	2 hrs	Directly from table	32
95	45 mins	No column for 45 minutes so add together values from 30 and 15 minute columns in row corresponding to 95dB.	65 + 32 = 97
Total exposure points			149

5. The total exposure points for this case is 20 + 32 + 97 = 149. This breaks the UEAV of 100 points but is within the ELV of 160 points. Using the converter at Table 2 it can be seen that 149 points works out at 86-87dB. The 45 minutes at 95dB provides the single largest contribution to daily noise points.

6. Using this system it is easy to predict how an individual's exposure would change following a reorganisation of work. Using the above example, if the employee were to spend 15 extra minutes at 95dB the individual performing this work would now be exposed to an extra 32 points. This would increase the total exposure points to 149 + 32 = 181. This would take the total above the ELV of 160 points and thus means of reducing the individual's daily noise exposure would be required.

ANNEX B TO
OEM/51/08
DATED SEP 08

LIST OF EQUIPMENT USED DURING THE SURVEY

Type	Model	Serial Number	Date of Last Calibration
Acoustic Calibrator	B&K 4231	1771096	25-Apr-07
Acoustic Calibrator	B&K 4231	1882677	25-Apr-07
Acoustic Calibrator	B&K 4231	1882679	25-Apr-07
Acoustic Calibrator	B&K 4231	2431911	25-Apr-07
EDIROL Solid-State Recorder	Roland R-09	AU97870	N/A
EDIROL Solid-State Recorder	Roland R-09	AU98355	N/A
EDIROL Solid-State Recorder	Roland R-09	BV05256	N/A
EDIROL Solid-State Recorder	Roland R-09	BV05309	N/A
EDIROL Solid-State Recorder	Roland R-09	FV89070	N/A
EDIROL Solid-State Recorder	Roland R-09	FV88918	N/A
EDIROL Solid-State Recorder	Roland R-09	GW06610	N/A
EDIROL Solid-State Recorder	Roland R-09	GW06383	N/A
EDIROL Solid-State Recorder	Roland R-09	GW06615	N/A
EDIROL Solid-State Recorder	Roland R-09	GW06618	N/A
EDIROL Solid-State Recorder	Roland R-09	BV04710	N/A
EDIROL Solid-State Recorder	Roland R-09	GW06623	N/A
EDIROL Solid-State Recorder	Roland R-09	GW06191	N/A
Miniature Microphone Sets (x13)	Knowles 1785	N/A	N/A
Microphone (1/2")	B&K 4190	1907569	11-Apr-03
Microphone Power Supply	OPUS	PVE-1315	N/A
Microphone Pre-amplifier	B&K 2669	1865453	N/A

NOISE EXPOSURE DATA FOR C2 AIRCRAFT CREW

Table 1 – C2 Cockpit Crew Noise Data

Date	Position	Ambient L_{eq} (dB(A))	At-ear L_{eq} (dB(A))	Measurement Duration (hh:mm:ss)	SNR (dB)
14-Feb-08	Engineer	78.3	84.0	08:25:04	9.2
14-Feb-08	Left-hand pilot	78.0	85.9	06:10:23	11.3
14-Feb-08	Right-hand pilot	77.9	88.1	08:54:23	12.5
21-Feb-08	Left-hand pilot	78.0	83.3	02:37:23	8.7
21-Feb-08	Engineer	79.6	83.4	04:39:40	8.8
21-Feb-08	Right-hand pilot	80.2	87.4	04:33:16	12.5
21-Feb-08	Left-hand pilot	82.7	87.8	05:18:20	14.6
21-Feb-08	Right-hand pilot	78.7	83.4	04:57:37	14.3
21-Feb-08	Engineer	78.9	82.4	05:32:43	7.7
	Worst Case	82.7	88.1	-	14.6

NOISE EXPOSURE DATA FOR K1 AIRCRAFT CREW

Table 1 – K1 Cockpit Crew Noise Data

Date	Position	Ambient L_{eq} (dB(A))	At-ear L_{eq} (dB(A))	Measurement Duration (hh:mm:ss)	SNR (dB)
4-Jul-07	Engineer	83.1	87.4	03:16:38	19.3
4-Jul-07	Left-hand pilot	81.6	83.6	05:20:56	9.2
4-Jul-07	Right-hand pilot	80.2	87.3	02:18:45	8.3
	Worst Case	83.1	87.4	-	19.3

Table 2 – K1 Cabin Crew Noise Data

Date	Position	Channel 1 L_{eq} (dB(A))	Channel 2 L_{eq} (dB(A))	Measurement Duration (hh:mm:ss)	Worst-case L_{eq} (dB(A))
4-Jul-07	Loadmaster	85.6	83.2	04:24:14	85.6
				Overall Worst Case	85.6

NOISE EXPOSURE DATA FOR KC1 AIRCRAFT CREW

Table 1 – KC1 Cockpit Crew Noise Data

Date	Position	Ambient L_{eq} (dB(A))	At-ear L_{eq} (dB(A))	Measurement Duration (hh:mm:ss)	SNR (dB)
16-Oct-07	Engineer	83.9	90.7	02:34:56	12.4
16-Oct-07	Left-hand pilot	83.9	90.2	02:24:47	10.6
16-Oct-07	Right-hand pilot	82.1	90.4	02:47:19	8.4
6-Dec-07	Left-hand pilot	86.1	88.6	02:08:20	8.2
6-Dec-07	Engineer	83.9	87.1	03:12:29	7.0
6-Dec-07	Right-hand pilot	82.5	89.3	04:57:44	9.8
13-Dec-07	Engineer	82.3	88.2	02:21:13	6.5
13-Dec-07	Left-hand pilot	80.6	88.1	05:26:13	8.4
13-Dec-07	Right-hand pilot	80.6	88.9	05:22:29	9.1
17-Jan-08	Engineer	80.2	84.1	04:26:35	10.9
17-Jan-08	Right-hand pilot	80.1	83.4	03:13:11	8.3
17-Jan-08	Left-hand pilot	78.9	85.5	03:06:22	12.3
22-Jan-08	Engineer	84.8	89.4	05:05:00	11.1
22-Jan-08	Left-hand pilot	85.7	89.1	05:01:40	5.3
22-Jan-08	Right-hand pilot	82.2	90.0	05:42:48	9.2
23-Jan-08	Engineer	84.3	91.2	05:20:18	9.6
23-Jan-08	Left-hand pilot	83.9	90.6	05:21:43	9.7
23-Jan-08	Right-hand pilot	82.7	87.7	05:26:10	6.7
	Worst case	86.1	91.2	-	12.4

Table 2 – KC1 Cabin Crew Noise Data

Date	Position	Channel 1 L_{eq} (dB(A))	Channel 2 L_{eq} (dB(A))	Measurement Duration (hh:mm:ss)	Worst Case L_{eq} (dB(A))
13-Dec-07	Air steward, front	86.5	87.8	04:55:08	87.8
13-Dec-07	Loadmaster	86.0	86.2	05:17:30	86.2
17-Jan-08	Air steward	80.0	79.5	02:40:43	80.0
17-Jan-08	Loadmaster	80.5	80.9	03:09:20	80.9
22-Jan-08	Air steward, front	84.8	83.8	04:20:08	84.8
22-Jan-08	Air steward, rear	86.9	86.8	04:40:13	86.9
22-Jan-08	Air steward, middle	85.1	85.9	04:30:11	85.9
23-Jan-08	Air steward, front	86.3	85.8	04:47:44	86.3
23-Jan-08	Air steward, rear	85.3	85.8	04:54:46	85.8
23-Jan-08	Air steward, middle	86.3	85.9	03:47:41	86.3
				Overall Worst Case	87.8

Worst Case Rear Steward	86.9
Worst Case Middle Steward	86.3
Worst Case Front Steward	87.8
Worst Case Loadmaster	86.2

ANNEX F TO
OEM/51/08
DATED SEP 08

PASSENGER SEATING NOISE MAPS

Table 1 – Worst Case C2 Passenger Seating Noise Map (Noise Levels In dB(A))

	A	B	C	D	E	F	G	H	J
1	-	-	-	-	-	-	-	79.6	-
2	-	-	78.5	-	-	-	-	-	-
3	-	-	78.5	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-
5	-	-	77.3	76.8	-	76.8	77.6	-	-
6	-	-	78.7	-	-	-	-	-	-
7	-	-	-	78.7	-	77.2	77.8	-	-
8	-	-	78.3	77.3	-	77.4	78.7	-	-
9	-	-	77.4	77.8	-	77.4	79.4	-	-
10	-	-	-	77.3	-	-	79.8	-	-
11	-	-	78.8	76.9	-	-	79.2	-	79.6
12	-	-	77.6	76.1	-	-	78.2	79.4	-
13	-	-	77.4	76.5	-	-	77.7	77.4	-
14	-	-	76.8	76.7	-	-	77	77.4	-
15	-	-	76.3	75.2	-	-	77.1	76.5	-
16	-	-	75.6	75.7	-	-	76.2	76.7	-
17	-	-	75.4	76.2	-	-	75.4	76.4	-
18	-	-	75.7	77.4	-	-	-	-	-
19	-	-	77	-	-	-	-	78.2	-
20	-	-	76.5	-	-	-	-	77.3	-
21	-	-	76.8	-	-	-	-	77.7	-
22	-	-	76.6	77.1	-	-	77.2	76.8	-
23	-	-	77.7	77.1	-	-	77.3	77.1	-
24	-	-	77.9	77.4	-	-	76.8	76.9	-
25	-	-	78.5	77.6	-	-	77.2	77	-
26	-	-	78.1	78.3	-	-	77.7	77.6	-
27	-	-	79.1	78.6	-	76.9	-	77.5	-
28	-	-	78.8	78.5	-	77.3	-	78.5	-
29	-	-	79.6	80.2	-	77.9	-	78.9	-
30	-	82.7	79.4	80.5	-	79.2	-	-	79.5

Table 2 – Worst Case K1 Passenger Seating Noise Map (Noise Levels in dB(A))

	A	B	C	D	E	F	G	H	J	K
1	-	-	-	77.4	76.1	-	76.1	-	-	-
2	81.8	77.1	79.5	74.7	76.0	-	76.1	76.3	-	78.7
3	83.2	76.7	78.7	75.0	74.4	-	74.0	75.7	-	-
4	80.7	75.8	78.7	75.1	74.4	-	73.0	75.2	-	78.1
5	79.9	75.7	76.6	74.2	73.4	-	73.0	74.7	-	78.1
6	79.2	75.5	76.2	79.1	77.8	-	73.0	74.6	-	78.4
7	80.0	74.6	75.3	72.0	-	-	-	73.9	-	77.5
8	83.4	75.1	74.8	-	-	-	72.0	74.3	-	76.5
9	78.9	75.7	74.1	-	-	-	73.0	74.0	-	77.7
10	77.9	74.9	74.7	-	-	-	74.0	74.0	-	-
11	76.6	74.6	74.5	-	-	-	76.0	74.0	-	78.0
12	75.9	78.2	76.1	-	-	-	79.0	75.0	85.9	84.5
13	77.2	78.6	75.4	-	-	-	80.0	-	-	-
14	78.6	80.0	77.8	-	-	-	81.0	-	79.0	80.8
15	80.4	79.0	77.7	82.4	81.7	-	82.0	-	78.6	-
16	83.2	81.0	80.7	82.9	83.0	-	82.0	78.9	78.8	80.5
17	81.9	81.1	80.7	84.6	83.8	82.0	-	-	-	80.8
18	83.3	83.3	83.6	84.5	83.6	83.0	-	79.6	78.6	80.0
19	84.1	83.3	83.4	84.6	84.2	84.0	-	-	-	-
20	85.8	85.0	87.1	-	-	-	-	-	86.5	83.9
21	87.1	86.5	-	-	-	-	-	-	-	-

Table 3 – Worst Case KC1 Passenger Seating Noise Map (Noise Levels In dB(A))

Seating Behind Cockpit						
83.4	83.0	83.2		82.9	83.0	83.2
81.5	-	82.3		-	-	83.0

	A	B	C	D	E	F	G	H	J
1	-	-	-	-	-	-	86.0	87.8	88.0
2	-	-	-	-	-	85.6	85.8	87.0	86.8
3	-	-	-	-	-	84.6	85.0	86.3	86.3
4	-	-	-	-	-	83.9	84.2	86.4	84.5
5	-	-	-	-	-	83.1	83.2	84.1	84.6
6	-	-	-	-	-	84.2	83.9	84.5	85.6
7	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	80.5	79.4	86.9	87.5
11	-	-	-	-	-	78.7	83.8	82.9	85.8
12	87.3	-	-	-	87.1	81.8	81.0	82.0	85.0
13	-	-	-	-	-	80.0	79.1	78.0	79.1
14	-	-	-	-	-	77.3	76.3	81.3	78.3
15	-	-	-	-	-	78.3	78.5	78.2	78.2
16	88.2	85.4	-	88.6	89.8	88.2	89.3	79.9	88.8
17	87.1	83.9	84.3	-	84.1	79.8	86.3	83.0	84.0
18	82.9	79.5	-	82.3	-	82.1	79.5	81.8	81.9
19	80.9	81.2	81.7	77.8	81.2	78.2	81.4	78.9	81.3
20	82.6	-	79.8	80.0	79.2	80.6	79.9	80.3	86.3
21	87.4	80.9	-	83.4	79.7	83.5	80.1	84.6	82.2
22	83.9	85.1	-	80.3	82.7	79.9	82.9	84.8	-
23	84.9	76.6	84.0	-	83.4	-	83.4	82.0	87.9
24	85.4	81.8	81.9	79.6	81.0	-	81.5	-	84.2
25	86.5	79.2	82.6	84.4	81.3	80.1	81.9	78.9	84.0
26	90.1	88.0	86.9	82.5	86.3	83.2	85.6	82.0	85.0
27	91.4	84.8	83.8	87.2	82.9	86.6	82.9	87.6	85.8
28	-	-	-	-	83.3	86.9	84.4	88.4	84.8
29	-	-	-	-	89.9	86.2	88.1	84.7	91.1
30	-	-	-	-	89.8	88.1	88.9	-	-
31	-	-	-	-	84.2	-	86.1	-	-

REPORT SUMMARY

Reference:

A. Programme Level Survey Protocol for DES-SE-Air sponsored Aircraft Noise and Vibration surveys – Issue 1 QinetiQ ix dated 07 Sep 07.

1. A summary of the attached report is presented here in accordance with Reference A.

a. **Aircraft Variants:** TriStar C2, K1 and KC1.

b. **Persons Covered:** Cockpit crew: left-hand pilots, right-hand pilots, engineers; Cabin crew: air stewards (front, middle and rear); Loadmasters.

c. **Helmets Covered:** N/A.

d. **Activities Covered:**

(1) Circuit flying.

(2) Air-air refuelling.

(3) Passenger transport.

e. **L_{Aeq} Values (Worst Case):** Table 1 shows the worst case L_{Aeq} values for the different personnel aboard the 3 TriStar variants. Cockpit crew values are at-ear and include communications noise. Stewards, Loadmasters and seat values are ambient noise levels.

Table 1 – Worst Case L_{eq} Values

		Worst Case L_{eq} (dB(A))
C2	Stewards	85
	Cockpit crew	88
	Loadmaster	82
	Seat 30B	83
K1	Cockpit crew	87
	Loadmaster	86
	Seat 20C and 21A	87
KC1	Stewards	88
	Cockpit crew	91
	Loadmaster	86
	Seat 27A	91

(NB. The worst case values for the cockpit crew are all at-ear, and include the communications noise.)

f. **Maximum Daily Exposure Times and Exposure Points Per 5 Minutes:** Table 2 shows the worst case exposure values and exposure points per 5 minutes for the different personnel aboard the 3 TriStar variants.

Table 2 – Worst Case Maximum Daily Exposure Times and Worst Case Exposure Points per 5 Minutes

Variant	Crew	Maximum Daily Exposure Times (HH:MM)			Exposure Points per 5 Minutes
		LEAV	UEAV	ELV	
C2	Stewards	02:31	08:00	12:40	1.0
	Cockpit crew	01:16	04:00	06:21	2.1
	Loadmaster	05:02	15:57	25:17	0.5
	Seat 30B	04:00	12:40	20:05	0.7
K1	Cockpit crew	01:35	05:02	08:00	1.6
	Loadmaster	02:00	06:21	10:04	1.3
	Seats 20C and 21A	01:35	05:02	08:00	1.6
KC1	Stewards	01:16	04:00	06:21	2.1
	Cockpit crew	00:38	02:00	03:11	4.1
	Loadmaster	02:00	06:21	10:04	1.3
	Seat 27A	00:38	02:00	03:11	4.1

g. **Comparison of Calculated Exposure with Action and Limit Values:** Sortie duration will typically be expected to exceed the Lower Exposure Action Value (LEAV), in all cases, but, while cockpit crew may well face exposure approaching Upper and Limit Exposure Values (UEAV and ELV), on C2 and K1 cabin crew, loadmasters and passengers would not be expected to breech these. KC1 appears to be a louder aircraft, and in this case it is entirely likely that cabin crew may break Upper daily exposure values on a routine sortie.

h. **Interpretation and Recommendations:**

(1) Since the lower action value will typically be exceeded, all aircraft crew are at risk of suffering from NIHL, and it would be advisable to take steps to reduce exposure. While reduced sortie length (and therefore reduced exposure time) may not be practicable, other solutions are available.

(2) Given the ambient noise levels recorded aboard the TriStar it would be advisable that the cabin crew and loadmasters wear the hearing protection that is available to them. On the C2 variant, which is quieter, this is not such an issue, but on the KC1 hearing protection for the cabin crew and passengers would certainly be recommended, particularly for those situated towards the back of the aircraft.

(3) In the case of the cockpit crew, reduced SNR, by way of reduced communications volume would be beneficial. If this can be achieved without affecting speech intelligibility for the pilots then reducing communications volume by even 1 or 2 decibels would improve the situation. Likewise, if steps could be taken to reduce or eliminate the constant noise being transmitted by the communications system (mentioned in the discussion section of the report) then this would also be beneficial. The communication system could also be improved with bandpass filters, in order to improve the quality of communications by eliminating unnecessary frequencies. Also, the ambient

noise in the cockpit was found to be lower when the door to the cabin was closed. If it could be open as little as possible, then this would help to reduce the exposure endured by the cockpit crew.

(4) By working to weekly rather than daily limits it may be possible to fly long sorties and avoid the issue of excessive exposure time.

(5) All flying personnel should be made aware of the risks of NIHL, and the merits of keeping communications volume to a minimum. It should also be ensured that all helmets are well fitted, to maximise the protection offered.

i. **Measures to be Considered:**

(1) Reduced communications volume if at all possible.

(2) Bandpass filters to improve the quality of the communication system.

(3) Education of the aircraft crew regarding the risks of NIHL.

j. **Signal-to-Noise Ratio Values:** Table 3 shows the worst-case and average Signal-to-Noise Ratio (SNR) values for cockpit crew aboard the 3 Tristar variants.

Table 3 – Worst Case and Average SNR Values

	SNR (dB(A))	
Variant	**Worst Case**	**Average**
C2	15	11
K1	19	12
KC1	12	9

k. **Significant Identified Contributors to Exposure:**

(1) Engine noise.

(2) Air flow noise.

(3) Air conditioning.

(4) Communications.

(5) Warning signals.

(6) Galley equipment: refrigerators, cookers, etc (applicable only to cabin crew).