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**A continuing study of F-111
Deseal/Reseal personnel
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Abbreviations

AIHW	Australian Institute of Health and Welfare
BOI	Board of Inquiry (A military Board of Inquiry has the same powers as a Royal Commission)
CI	Confidence Interval
DSRS	Deseal/Reseal
DVA	Department of Veterans' Affairs
HWE	healthy worker effect
ICD-10	International statistical classification of diseases and related health problems, 10 th revision
MCIS ^{2nd}	SHOAMP Mortality and Cancer Incidence Study, 2 nd report 2004
NCSCH	National Cancer Statistics Clearing House
NDI	National Death Index
RAAF	Royal Australian Air Force
RR	relative rate
SHOAMP	Study of Health Outcomes in Aircraft Maintenance Personnel
SIR	standardised incidence ratio
SMR	standardised mortality ratio
TUNRA	The University of Newcastle Research Associates
USAF	United States Air Force

Summary

About this report

This report is the third study into mortality and cancer incidence in 873 male personnel involved in the F-111 aircraft Deseal/Reseal (DSRS) programs at RAAF Base Amberley between 1977 and 1999. The incidence rates for DSRS personnel were compared with those of the Australian male population and two comparison groups from RAAF Base Amberley and RAAF Base Richmond.

The first and second mortality and cancer incidence studies were undertaken in 2003 and 2004 respectively as part of the larger Study of Health Outcomes in Aircraft Maintenance Personnel (SHOAMP). The SHOAMP followed a Royal Australian Air Force Board of Inquiry (BOI) that was convened in 2000 following concerns that personnel had raised health risks due to exposure to the chemicals used in the spray sealing of F-111 fuel tanks in 1999.

The second mortality and cancer incidence study utilised the National Death Index (NDI) to identify deaths for the period up to 2001, and the National Cancer Statistics Clearing House (NCSCCH) to identify cancers for the period up to 2000.

This third study utilises more recent data – the NDI to identify deaths for the period 1980-2004, and the NCSCCH to identify cancers for the period 1982-2003. In addition, this study separates 1999-2004 mortality data to reduce the bias associated with non-identification of personnel before 1999.

Key findings

Findings from this study are consistent with findings from the previous study.

- Overall cancer incidence in male personnel who were involved in DSRS programs was elevated by 44% when compared with the Australian male population; however the very small number of people involved means that this result was not statistically significant.
- Lip cancer incidence in DSRS personnel was four times as high as in the general Australian male population. This result was statistically significant, but based on only four cases.
- Overall mortality was lower for DSRS personnel when compared with the Australian male population; however, mortality, based on two cases of non-Hodgkin lymphoma, was higher than expected in the 1999-2004 period.
- Cancer incidence in personnel in the two comparison groups (RAAF Base Richmond in New South Wales and RAAF Base Amberley in Queensland) was similar to that of the Australian male population.
- Overall mortality for the two comparison groups was lower than for the Australian male population; these results were statistically significant.
- Comparing the exposed groups (the DSRS personnel) with Amberley personnel showed no significant differences in mortality or cancer incidence.

- Comparing the exposed groups (the DSRS personnel) with Richmond personnel showed increased cancer incidence which was statistically significant. The results for mortality were less clear, with analysis of deaths in the period 1980–2004 showing a statistically significant lower rate, whereas analysis for the period 1999–2004 showed a statistically non-significant higher rate.

Given the number of borderline significant and non-significant findings, the AIHW believes that current data is inconclusive and recommends that this study be repeated in 2011 when more data will be available to provide greater statistical power and to improve certainty about the findings.

1 Introduction

Background

In 1963, Australia ordered 24 F-111 aircraft from General Dynamics in the United States of America. Following delays due to a design problem, these aircraft were finally delivered in June 1973. This purchase was later supplemented by younger aircraft of the same type which arrived in October 1992. Soon after the original aircraft were delivered, the sealant in the fuel tanks of these aircraft began to revert, causing the fuel tanks to leak. This problem was rectified by removing the sealant and replacing it with new sealant. As the problem grew, aircraft were removed from service and subject to a process known as Deseal/Reseal (DSRS). During the period 1977–1999, four formal DSRS programs (see below) were carried out on the F-111 fleet of aircraft by aircraft maintenance workers at RAAF Base Amberley.

In 2000, due to health concerns about the effects of exposure to chemicals used in the spray seal program, a Unit Inquiry was initiated. When the extent of the problems was realised a Board of Inquiry (BOI) was convened. During the BOI and subsequently, a health study was undertaken on the personnel involved.

This report describes the results of a follow-up study into 2004 mortality and cancer incidence in 873 male personnel involved in the F-111 aircraft DSRS programs between 1977 and 1999.

What follows is background information on the DSRS programs, the RAAF Board of Inquiry (BOI) and the initial studies. Section 2 of this report presents the results of the current health study. Section 3 contains a discussion about these results and briefly describes the new 2006 results in relation to the previous 2004 study. Detailed information about the methods used for analysis, and detailed statistical tables, can be found in the appendices at the end of this report.

The programs

From 1973–1977, fuel tank leak repairs carried out on the F-111 aircraft were ‘ad hoc’ with leaks repaired as they occurred. However as the problem of leaks grew, a decision was made to address the problem systematically. Following this decision, the first DSRS program (Program 1) was conducted between 1977 and 1982; Program 2 from 1990 to 1993; the ‘Wing DSRS’ Program from 1985 to 1992 and the ‘Spray Seal’ Program from 1996 to 1999. These four programs are collectively referred to as the four formal DSRS programs. Earlier DSRS work was conducted at Sacramento from 1975 on United States Air Force (USAF) aircraft. Australia sent nine aircraft to Sacramento between May 1981 and December 1982 for maintenance under contract by the USAF. No RAAF personnel were involved.

During the four formal DSRS programs, a number of chemicals and processes were used. However, these chemicals were not used across all four programs. For a discussion on the chemicals and processes readers are invited to read the BOI Report – Vol 2 Chapter 7 (Defence 2001).

In addition to the aircraft maintenance workers who participated in any of the four formal DSRS programs, there were a number of aircraft maintenance workers who entered the F-111 fuel tanks to carry out fuel tank leak repairs which was commonly known as 'pick and patch'. However, except in order to correct leaks after a full scale DSRS procedure, 'pick and patch' was not conducted as part of the four formal DSRS programs.

The RAAF Board of Inquiry

In response to health concerns raised by those involved in the Spray Seal Program in 1999, a Unit Inquiry was instigated which quickly determined that there were problems associated with the Programs going back to 1977. When the extent of issues began to emerge, Chief of Air Force convened a Board of Inquiry (BOI) in July 2000. The BOI was required to inquire and make findings in relation to each of the four formal DSRS programs (excluding 'pick and patch').

The BOI made extensive inquiries into the processes, procedures and chemicals used during the programs and reported in great detail on the systemic causes of a break down in safety management. However, the combined effect of the chemicals used in the four formal DSRS programs was not and could not be researched. Nevertheless, the principal finding of the BOI was the estimate *'that in excess of 400 people (who had participated in the four formal DSRS programs) have suffered long-term health effects as a result of such exposure (to chemicals)*(Defence 2001).

There were 56 recommendations from the BOI which have had a profound effect on how safety is managed not only in Air Force but across the whole of the ADF. The resulting changes will take many years to fully implement.

SHOAMP studies

As a result of the BOI, Defence commissioned an epidemiological study into the health impacts of participation in the DSRS programs. This study, known as the Study of Health Outcomes in Aircraft Maintenance Personnel (SHOAMP), examined the health of personnel involved in the four formal F-111 DSRS programs and compared this to personnel from RAAF Base Amberley and RAAF Base Richmond.

There were a variety of exposures that occurred during the four formal DSRS programs. The health effects of these exposures were documented in the literature review conducted as part of the SHOAMP (TUNRA 2003a).

SHOAMP included a literature review, a General Health and Medical study, and the two Mortality and Cancer Incidence studies (TUNRA 2003a; TUNRA 2003b; TUNRA 2004a and TUNRA 2004b). The second MCIS study repeated the mortality and cancer incidence component of the first, but used improved analytical statistical/epidemiological matching techniques, used updated cancer and death data (up to December 2000 and 2001 respectively), and had a longer lag time between DSRS activities and possible adverse health outcomes. The second study is known as the SHOAMP Mortality and Cancer Incidence Study, 2nd (MCIS 2nd).

In both studies, the mortality and cancer incidence rates of DSRS personnel were compared with the Australian male population, as well as with two comparison groups from RAAF Base Amberley and RAAF Base Richmond. The MCIS 2nd found that there was a probable

higher cancer incidence rate among DSRS personnel; however it was evident that the period between the DSRS programs and the study was not sufficient to allow for more significant outcomes. The study investigators also noted that the exposed group did not exhibit the same increased mortality rate from cancer. They suggested that this finding was due to 'survivor bias'. Despite using a variety of processes to reconstruct a list of DSRS personnel, a mortality analysis undertaken by an independent scientific team (Attia et al. 2006) suggested that this list of personnel was incomplete.

The investigators of the 2004 MCIS 2nd recommended repeating the study in 3 to 5 years when more outcome events became available to increase the power of the Study. This current 2006 report represents the implementation of that recommendation.

At the time of writing the oldest known living participant of the DSRS programs came from Program 1 and was 74 years old. The majority of participants are now aged in their 50s and 60s, and were involved in Program 2 and the 'Wings' Program. The youngest participants, who are in their 30s, took part in the Spray Seal Program. Given the latency of symptoms already observed in those from Program 1, these men may not show any signs or symptoms for another 20 or 30 years.

Statistics presented in this report

Two types of comparative analysis are presented here. Each of these involves comparing the number of observed cancers/deaths to the expected number, where the expected number is calculated by applying 'standard' rates to the exposed group(s). Depending on the results presented, the 'standard' rates are derived either from the total Australian male population, or from the combination of the exposed and comparison groups.

In each table the observed and expected *numbers* are shown, and the text refers to levels of incidence in the study groups being higher, lower or the same as in the comparison groups. In each instance, comparative statements should be understood as relative assessments, having taken population size into account. Readers should also note that rates, while large, are often based on small numbers.

For a further discussion about the statistical methods used in the study, please refer to Appendix 1.

2 Results

Cancer incidence, standardised comparison with Australian males

This section of the report describes the incidence of cancer in various study groups from 1982–2003 using standardised incidence ratios (SIRs). The latest study identified 632 cancers – 40 in the exposed group (DSRS group), 302 in the Amberley group and 290 in the Richmond group. The Amberley group included 7,577 personnel working on base (that is the same base as those in the DSRS programs), but who were involved in non-technical activities. The Richmond group included 9,408 personnel involved in technical trades, including aircraft maintenance activities, but none of whom was known to have been involved in DSRS activities.

Exposed group (DSRS group)

Cancer incidence for the exposed group was higher than expected (40 reported cases rather than the expected 28) when compared to cancer incidence in the Australian male population (Table 2.1). This result (44% higher) was not statistically significant. Incidence for lip cancer in particular was elevated (over 3 times), and this result was statistically significant. Incidence of other cancers was elevated but the results were not statistically significant (Table A2.1).

Table 2.1: Observed and expected number of cancers for all exposed personnel and the standardised incidence ratio (SIR) for selected cancers, 1982–2003

Cancer type	Observed	Expected	SIR	95% Confidence Interval (CI)
All cancers ^(a)	40	28	1.44	0.99–1.88
Lip	4	1	*4.13	1.12–10.56
Leukaemia	1	1	1.11	0.03–6.20
Lung	4	2	1.97	0.54–5.04

* Findings statistically significant.

(a) Excludes non-melanocytic skin cancers.

Leukaemia and lung cancer have been associated with exposure to organic solvents and hexavalent chromate compounds. The incidence of lung cancer was higher in the exposed group, though not to a statistically significant level; the incidence of leukaemia was similar to that in the Australian male population.

Results for individual programs within the exposed group – Program 1, Program 2 and ‘Other’ (that is, Wing and Spray Seal program) – were similar to the overall exposed group results. They all showed a non-significant increase in the incidence of overall cancer of about 40% (tables A2.4, A2.5, and A2.6). Some individual types of cancers were also elevated but none were significant.

Amberley group

The Amberley group had similar cancer incidence compared with the Australian male population, with the exception of two statistically significant results: connective soft tissue cancer was 2.5 times higher and prostate cancer was significantly lower than the Australian male population (tables 2.2 and A2.2).

The incidences of leukaemia and lung cancer were similar to the Australian male population.

Table 2.2: Observed and expected number of cancers for Amberley personnel and the standardised incidence ratio (SIR) for selected cancers, 1982–2003

Cancer type	Observed	Expected	SIR	95% CI
All cancers ^(a)	302	300	1.01	0.89–1.12
Connective soft tissue	8	3	*2.52	1.12–4.97
Prostate	47	68	*0.69	0.49–0.89
Leukaemia	9	9	1.00	0.46–1.89
Lung	27	27	1.00	0.62–1.38

* Findings statistically significant.

(a) Excludes non-melanocytic skin cancers.

Richmond group

Like the Amberley group, the Richmond group had similar levels of cancer incidence when compared with the Australian male population, and significantly lower levels of prostate cancer (tables 2.3 and A2.3).

The incidence of leukaemia and lung cancer was lower than the Australian male population, but not statistically significant. The incidence of brain cancer was elevated, but was still not statistically significant.

Table 2.3: Observed and expected number of cancers for Richmond personnel and the standardised incidence ratio (SIR) for selected cancers, 1982–2003

Cancer type	Observed	Expected	SIR	95% CI
All cancers ^(a)	290	297	0.98	0.86–1.09
Brain	16	9	1.73	0.99–2.81
Prostate	36	58	*0.62	0.42–0.82
Leukaemia	7	9	0.74	0.30–1.53
Lung	15	23	0.65	0.36–1.07

* Findings statistically significant.

(a) Excludes non-melanocytic skin cancers.

Mortality, standardised comparison with Australian males

Mortality in the study groups was compared with the general Australian male population using standardised mortality ratios (SMRs) calculated for the periods 1980–2004 and 1999–2004. The separation of the 1999–2004 data enables a more reliable analysis as it reduces the bias associated with non-identification of personnel before 1999 (see Mortality analysis, page 12). However, there are fewer data for the 1999–2004 period, which limits the power of the analyses.

Exposed group

Using the Australian male population as a reference, the 1980–2004 analysis showed that the exposed group had less than half the number of deaths expected, and this was statistically significant (tables 2.4 and A2.7). The 1999–2004 analysis, however, showed approximately the same levels of mortality as for the Australian male population.

Table 2.4: Observed and expected number of deaths for all exposed personnel and the standardised mortality ratio (SMR), selected causes of death, 1980–2004 and 1999–2004

Cause of death	1980–2004				1999–2004			
	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI
All deaths	16	38	*0.42	0.24–0.69	13	14	0.91	0.49–1.56
Neoplasms	9	9	0.96	0.44–1.82	7	5	1.52	0.61–3.12
Leukaemia	0	0	—	—	0	0	—	—
Lung	3	2	1.68	0.35–4.92	2	1	2.09	0.25–7.55
NHL ^(a)	2	1	3.76	0.45–13.58	2	0	*9.67	1.17–34.92
Circulatory system	2	8	*0.26	0.03–0.92	1	3	0.29	0.01–1.61

* Findings statistically significant.

(a) Non-Hodgkin lymphoma.

For specific cancers, the number of deaths in the exposed group was greater than expected; those due to non-Hodgkin lymphoma (NHL) were statistically significant in the period 1999–2004. Deaths due to cardiovascular disease (disease of the circulatory system) were very low in both analyses but only statistically significant in the period 1980–2004. In the exposed group there were no leukaemia deaths, but there were three lung cancer deaths (two deaths from 1999–2004). The higher number of deaths due to lung cancer was not statistically significant.

Results for Program 1 and Program 2 groups were similar to the overall exposed results (tables A2.10 and A2.11). Mortality in the exposed groups was 9% lower than that of the Australian male population; however this was not statistically significant. The 'Other' group had a level of mortality which was 6% lower (compared with the Australian male population), and this also was not statistically significant (Table A2.12).

Comparison groups

Survivor bias (see *Sources of bias*, page 11) did not affect mortality for the Amberley or Richmond group, as data for the comparison groups were collated by accessing the computerised personnel records of the RAAF for people who performed similar occupations (Richmond group) or worked on the same Base (Amberley group) to those involved in DSRS activities. Therefore the analysis for the period 1980–2004 for the comparison groups was considered sound.

Amberley group

Mortality in the Amberley group was 30% lower than for the general Australian male population for the period 1980–2004, and this result is statistically significant (tables 2.5 and A2.8). Deaths due to diseases of the circulatory system, in particular ischaemic heart disease, were 25% lower, and deaths due to liver, gall bladder and bile duct conditions were almost 60% lower. Deaths due to mental disorders were fewer than a quarter of those in the general Australian male population.

Table 2.5: Observed and expected number of deaths for Amberley personnel and the standardised mortality ratio (SMR), selected causes of death, 1980–2004 and 1999–2004

Cause of death	1980–2004				1999–2004			
	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI
All deaths	263	375	*0.70	0.62–0.79	113	149	*0.76	0.62–0.90
Neoplasms	95	110	0.86	0.69–1.04	50	53	0.95	0.69–1.21
Leukaemia	6	5	1.27	0.47–2.76	1	2	0.51	0.01–2.87
Lung	20	24	0.84	0.51–1.29	13	12	1.11	0.59–1.89
Mental disorders	2	9	*0.22	0.03–0.78	0	3	0.00	0.00–1.45
Circulatory system	68	93	*0.73	0.56–0.91	31	38	0.81	0.53–1.10
Ischaemic heart disease	47	63	*0.75	0.53–0.96	17	26	0.67	0.39–1.07
Liver, gall bladder, bile ducts	5	12	*0.41	0.13–0.96	1	5	0.20	0.01–1.14
External causes	55	97	*0.57	0.42–0.72	12	27	*0.44	0.23–0.77
Suicide	24	37	*0.65	0.39–0.91	5	11	0.45	0.14–1.04

* Findings statistically significant.

Richmond group

The 1980–2004 overall mortality in the Richmond group was 29% lower than in the general male population – the difference is statistically significant (tables 2.6 and A2.9). Mortality due to diseases of the circulatory system was nearly 35% lower than the Australian male population. Additionally, deaths from respiratory system diseases and for liver, gall bladder and bile duct conditions were respectively approximately 60% and 75% below levels of mortality in the general Australian male population. Similarly, deaths due to mental disorders were about 80% lower than expected.

Table 2.6: Observed and expected number of deaths for Richmond personnel and the standardised mortality ratio (SMR), selected causes of death, 1980–2004 and 1999–2004

Cause of death	1980–2004				1999–2004			
	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI
All deaths	279	395	*0.71	0.62–0.79	93	153	*0.61	0.48–0.73
Infectious and parasitic	0	7	*0.00	0.00–0.52	0	3	0.00	0.00–1.20
Neoplasms	90	103	0.87	0.69–1.06	36	50	*0.73	0.49–0.97
Leukaemia	4	5	0.81	0.22–2.07	0	2	0.00	0.00–1.93
Lung	14	20	0.69	0.38–1.15	5	10	0.48	0.16–1.12
Mental disorders	2	12	*0.17	0.02–0.60	0	3	0.00	0.00–1.22
Circulatory system	57	87	*0.66	0.49–0.83	22	37	*0.60	0.35–0.85
Ischaemic heart disease	34	58	*0.59	0.39–0.79	11	25	*0.45	0.22–0.80
Respiratory system	5	13	*0.39	0.13–0.91	3	6	0.51	0.11–1.49
Digestive system	6	16	*0.37	0.14–0.81	2	7	0.29	0.03–1.04
Liver, gall bladder, bile ducts	3	12	*0.24	0.05–0.71	1	5	0.19	0.00–1.05
External causes	107	124	0.86	0.70–1.02	24	35	*0.70	0.42–0.98
Assault	0	5	*0.00	0.00–0.67	0	1	0.00	0.00–2.65

* Findings statistically significant.

Mortality and cancer incidence, comparative analysis between the exposed and comparison groups

This section compares the mortality and cancer incidence between the exposed groups and the comparison groups (Amberley and Richmond). As a consequence of relatively small numbers of deaths and cancer incidence, only a limited number of causes of death and cancer types was investigated. Incidence for personnel in the 'Other' (Wing and Spray Seal Programs) was not analysed separately as there has been an insufficient amount of elapsed time to make meaningful observations (see page 1 for information about the years when the four formal DSRS programs were conducted).

Exposed and Amberley

Cancer incidence

The exposed group had higher cancer incidence rates than the Amberley group, but these rates were not statistically significant (Table 2.7); these findings held for both Program 1 and Program 2 (tables A2.13 and A2.14).

Mortality

Overall mortality in the exposed group for the 1999–2004 period was higher than the Amberley group by almost 30%; however this elevation was not statistically significant (Table 2.7). When compared against the individual programs, mortality was also elevated for the Program 1 group (by 13%); whereas the results for the Program 2 group differed only slightly (by 4%) from the Amberley group (tables A2.13 and A2.14). Again, these results were not statistically significant.

Table 2.7: Observed and expected number of cancers and deaths, and relative rate (RR), exposed personnel and Amberley comparison group, selected periods 1980–2004

Cancer/cause of death	Exposed		Amberley		RR	95% CI
	Observed	Expected	Observed	Expected		
All cancers ^{(a)(b)}	40	29	302	313	1.41	0.98–1.96
Colorectal	6	4	47	49	1.55	0.54–3.64
Lung	4	2	27	29	1.83	0.46–5.24
Lymphoid/haematopoietic	4	3	25	26	1.59	0.40–4.59
Melanoma	10	6	53	57	1.69	0.77–3.36
Prostate	5	3	47	49	1.53	0.47–3.82
All deaths 1980–2004	16	24	263	255	0.65	0.36–1.07
All neoplasm deaths 1980–2004	9	8	95	96	1.09	0.49–2.17
All deaths 1999–2004	13	10	113	116	1.28	0.66–2.27
All neoplasm deaths 1999–2004	7	5	50	52	1.57	0.60–3.48

(a) Excludes non-melanocytic skin cancers.

(b) All cancer incidences relate to the period 1982–2003.

Exposed and Richmond

Cancer incidence

The exposed group had an overall cancer incidence that was nearly 50% higher when compared with the Richmond group, and this difference was statistically significant (Table 2.8). Individual types of cancer incidences were all higher, but the differences were not statistically significant.

The analyses comparing Program 1 and the Richmond group show similar trends to the total exposed group (Table A2.15). Program 1 had 54% higher rate of cancer incidence than the Richmond comparison group; however this result was not statistically significant. All the investigated types of cancer had elevated rates, but none of these was statistically significant. The Program 2 group also had an elevated rate of cancer incidence when compared with the Richmond group; again, this was not statistically significant.

Mortality

The analysis of the mortality data for 1980–2004 showed that overall mortality for the exposed group was 40% lower than overall mortality for the Richmond group, and this was marginally statistically significant. However, the 1999–2004 analysis showed that mortality for the exposed group, though not statistically significant, was nearly twice as high as the Richmond group. In addition, deaths due to neoplasms in the exposed group were higher than that of the Richmond group. It should be noted that neither of the 1999–2004 results was statistically significant. The comparison between Program 1 and Program 2 groups and the Richmond group showed similar results to those of the whole exposed group (tables A2.15 and A2.16).

Table 2.8: Observed and expected number of cancers and deaths, and relative rate (RR), exposed personnel and Richmond comparison group, selected periods 1980–2004

Cancer/cause of death	Exposed		Richmond		RR	95% CI
	Observed	Expected	Observed	Expected		
All cancers ^{(a)(b)}	40	28	290	302	*1.48	1.03–2.06
Colorectal	6	3	30	33	2.15	0.73–5.24
Lung	4	2	15	17	2.88	0.70–9.06
Lymphoid/haematopoietic	4	3	32	33	1.33	0.34–3.74
Melanoma	10	7	67	70	1.55	0.71–3.04
Prostate	5	3	36	38	1.57	0.48–4.02
Cause of death						
All deaths 1980–2004	16	26	279	269	*0.60	0.34–0.99
All neoplasm deaths 1980–2004	9	8	89	90	1.11	0.49–2.20
All deaths 1999–2004	13	9	93	97	1.48	0.76–2.66
All neoplasm deaths 1999–2004	7	4	36	39	2.12	0.79–4.82

* Findings statistically significant.

(a) Excludes non-melanocytic skin cancers.

(b) All cancer incidences relate to the period 1982–2003.

3 Discussion

This report examines mortality and cancer incidence in the F-111 exposed groups and in two comparison groups. It provides a follow-up to the 2004 SHOAMP Mortality and Cancer Incidence Study (MCIS 2nd) to determine if the patterns of mortality and cancer incidence have changed over time.

Sources of bias

A number of biases were documented extensively in the MCIS 2nd, and some of these biases are discussed briefly here.

Survivor bias can occur when some study participants die before the start of the study and are not identified, leading to a falsely low mortality estimate. This has very likely occurred in the 1980–2004 mortality study of the exposed groups, but does not affect the 1999–2004 analysis. The comparison groups are not affected as these personnel were selected from RAAF records that are unaffected by early deaths.

Selection/volunteer bias can occur when people with health problems are more likely to participate in studies, and would have the affect of elevating cancer incidence (and possibly mortality) rates in the exposed groups.

The healthy worker effect (HWE) is a phenomenon observed in occupational health studies in which those who are employed exhibit a lower mortality rate than the general population. Occupational studies of military cohorts are especially affected as military populations are far healthier than other employed populations. This higher level of health and fitness is due to the active screening of those with chronic illnesses undertaken at enlistment into the military and the ongoing requirement to maintain good physical and mental health while serving. The HWE should affect the exposed and the comparison groups equally, and will make their SMRs lower when compared with Australian mortality. When military groups are compared with each other, the HWE should not affect the SMR.

Cancer analysis

In the MCIS 2nd, the investigators concluded ‘on the balance of probabilities, there is an increased risk of cancer associated with participation in the F-111 DSRS group’ (TUNRA 2004: 71). The current study repeated the analyses and found that the incidence of cancer in the exposed group, while not statistically significant, was 44% greater than the Australian male population. However, these results need to be interpreted carefully.

The exposed personnel had marginally higher (but statistically non-significant) rates of cancer incidence than the Amberley group. They also had incidence rates that were nearly 50% higher than the Richmond group, and these were marginally statistically significant. However, there were no specific cancers that appeared to be significantly elevated in the exposed group.

The results for the current study were similar to those found in the MCIS 2nd, showing a borderline statistically significant elevation in cancer incidence for the exposed group. This trend may become more pronounced over time, given the increasing age of the cohort as

well as the increased latency period between participation in the F-111 DSRS programs and the onset of cancer. This was demonstrated by the comparison of Program 1 and Program 2 groups against the Richmond group. The Program 1 group (who worked on DSRS from 1977 to 1982) had a marginally significant higher incidence of cancer, while the results for Program 2 (who worked on DSRS from 1990 to 1993) showed a statistically non-significant elevation. Increasing the time between DSRS and study will increase the power of the study and in turn provide more reliable results.

The Amberley and Richmond comparison groups had relatively similar incidences of cancer as the Australian male population. As there is no reason to believe that the cancer incidence in these groups would differ from the rest of the population, the results suggest that the methodology used in the study was robust.

Leukaemia and lung cancer

The investigators of the MCIS 2nd recommended an examination of specific cancers linked to organic solvents and hexavalent chromium exposure. Leukaemia and lung cancer are two conditions identified as associated with exposure to these compounds and so these were analysed in the current study as areas of interest. The study found that the incidence of leukaemia was similar to the Australian male population, and the incidence of lung cancer was higher in the exposed group, though not to a statistically significant level.

It is difficult to make generalisations from the results in the current study as there was limited power and the results were not statistically significant. Monitoring over time may improve the probability of findings for these specific cancers.

Lip cancer

The incidence of lip cancer was significantly elevated in the exposed group compared to the Australian male population. While this was only based on four cases, it was an unexpected result as there are no known occupational causes related to this cohort.

It is recommended that this type of cancer be monitored over time.

Mortality analysis

The results for the period 1980–2004 showed that the exposed group had a statistically significant lower mortality than the Australian male population, similar to the results found in the MCIS 2nd. This is likely, at least in part, due to survivor bias (TUNRA 2004).

In order to control for survivor bias in the exposed group, analysis of their mortality was examined from the time that the exposed group membership was almost complete. Although there is no certainty that all personnel with DSRS exposure have been identified, by 1999 the health risks associated with the DSRS program was a highly significant issue and efforts were underway to assemble lists of those personnel who were involved in DSRS activities.

In this report, a new analysis was undertaken to only examine data for the period 1999–2004. In this analysis, mortality in the exposed group was roughly similar to the Australian male population, but as there were relatively few deaths post 1999, the results do not have the same level of power and were not statistically significant.

The Amberley and Richmond comparison groups had a statistically significant lower level of mortality than the Australian male population, and this could be the result of a healthy worker effect.

The exposed DSRS group had a higher mortality rate in the period 1999–2004 than both the Amberley and the Richmond comparison groups; however, the elevations were not statistically significant in either comparison.

Conclusion

Overall, the results from the current 2006 cancer incidence study reflect those found in the MCIS 2nd, with this study finding that there was a higher, but not statistically significant, incidence of cancer in the exposed group.

The HWE distorted the mortality comparison with the Australian male population but not the direct comparison with the Amberley and Richmond groups. The 1980–2004 mortality analysis found a lower all-cause mortality rate in the exposed DSRS group, but cancer mortality was slightly elevated. However, these results were not statistically significant.

The 1999–2004 mortality analysis was considered a less biased analysis, and mortality rates for the exposed group were higher than the comparison groups, but none of the findings was statistically significant.

It is likely that the latency period between the DSRS programs and the study was not sufficient to allow for more significant outcomes. As recommended in the MCIS 2nd, mortality and cancer incidence, if monitored over time, will allow for more robust results. The National Cancer Statistics Clearing House is updated annually; cancer data for 2008 will become available for analysis in 2011. Future updates of this study will enable a longer latency period, hence a better estimate of cases, therefore increasing the power of the study and in turn providing more reliable results.

Appendix 1: Methods

This study is a retrospective cohort study and it used the same methodology that was used in the SHOAMP Mortality and Cancer Incidence Study (MCIS 2nd).

A retrospective cohort study requires several distinct steps as follows:

1. Identification of the study population and the comparison group(s) population.
2. Determination of the outcomes (in this case the incidences of cancer and mortality) during the study period for all populations.
3. Comparison of the health outcomes of the study population to the comparison groups.

Existing data

The study population and the comparison groups were identified in the original study referred to above. No changes were made to any of these groups.

Exposed group

The identities of the exposed personnel were determined from fuel tank repair records, RAAF posting and attachment records, and contractor staff records. Photographs were used to identify people who were working on the programs. These people were then able to name co-workers who had not been identified by other methods. At the time, the Department of Veterans' Affairs (DVA) worked to expand the cohort, primarily through advertising and running a hotline. Note thought that this results in 'self reporting'.

While every effort was made to include all exposed personnel, it is likely that the cohort is not complete. Of particular concern are those exposed personnel who died before the health risks were known.

The DSRS program consisted of four formal fuel tank DSRS programs – Program 1, Program 2, the Wing Program and the Spray Seal Program. The Wing Program and Spray Seal Program have been grouped together in this study under 'Other', as was done in the MCIS 2nd.

Of the 899 'potentially exposed' DSRS participants as identified in the SHOAMP, 22 females were excluded because this number was too small to study as a group and four males with missing date of birth information were also excluded, leaving a total of 873 males included in the exposed group. Of these, 389 participated in Program 1, 302 during Program 2, and 254 during 'Other' programs. Some personnel in the exposed group participated in more than one DSRS program.

Amberley comparison group

This comparison group included all male Air Force personnel posted to RAAF Base Amberley at the time the DSRS programs were conducted, but in non-technical job categories. These personnel had generally similar environmental exposures to the exposed group, but were not exposed to the aircraft maintenance duties in general and DSRS

specifically. This group should therefore not have been exposed to chemicals or hazards inherent in any form of aircraft maintenance.

The Amberley group comprised 7,577 males. There were 277 males who were included in both the Amberley and Richmond comparison groups.

Richmond comparison group

This comparison group consisted of all male Air Force personnel posted to RAAF Base Richmond at the time of DSRS programs or activities, in technical jobs. Most of these men would have been exposed to general aircraft maintenance other than DSRS.

The Richmond group comprised 9,408 males, including 277 who were also included in the Amberley comparison groups.

Previously identified cancer and mortality incidence cases

Using information from the National Death Index (NDI) and the National Cancer Statistics Clearing House (NCSCCH) – see below – the previous study identified cancer incidence cases for the period 1982 to 2000 and deaths for the period 1980 up to 2001. All these cancer and death cases were included in the current study.

Unlike the MCIS 2nd report where the researchers differentiated between first and all cancers and first and last posting, the current study examined all cancers and did not distinguish between first and last posting because it was considered that these analyses would not add value to the results, and had the potential to confuse the issue.

Missing causes of death

Two personnel in the Richmond comparison group were known to have died but their cause of death was not recorded (less than 1% of all Richmond deaths). This had no bearing on the 'all cause' analysis, but posed a problem for the cause-specific analysis. As there was no indication that these deaths were in any way different from known causes, they were assigned a cause of death according to the distribution of known causes.

New data

All populations were matched to the NDI to identify mortality for the period up to 2004, and matched to the NCSCCH to obtain cancers for the period up to 2003.

The NDI is a database maintained by the AIHW and contains records of all deaths occurring in Australia since 1980. The Registrars of Births, Deaths and Marriages in each state and territory supply all data contained in the NDI. Data, including the coded cause of death, were complete to 2004 at the time of the study.

The NCSCCH is a database maintained by the AIHW and contains records of all diagnosed cancers in Australia, excluding non-melanocytic skin cancer (but including melanoma). Cancer is a notifiable disease in Australia. Cancer registries in each state and territory collect information about individuals with newly diagnosed cancer and provide it to the NCSCCH for the compilation of national statistics and epidemiological studies. Matching with the

NCSCCH was undertaken by the AIHW with data from all states and territories except Victoria. Victorian data were matched by the Victorian cancer registry, using identical matching algorithms to those used by the AIHW.

The matching process

The matching process used probabilistic techniques where records are linked that are thought to relate to the same individual. The process is described as 'probabilistic' because for each linkage there is an associated degree of certainty that the records are correctly paired. The matching algorithms used were identical to the ones used in the original study.

The Study Roll (records of those in the exposed and comparison groups), the NDI and the NCSCCH were standardised to improve the likelihood of successfully matching records. This meant that apostrophes, hyphens and other miscellaneous characters were removed from surnames, and dates of birth and dates of death, where available, were presented within valid ranges. Soundex and New York State Intelligence Information System coded versions of the standardised surnames were created which allows for variations in spelling of names (for example, Smith, Smithe, and Smythe). Standard versions of first names were added to all files (for example, Robert for Bob and Rob). The matching algorithms used various combinations of the standardised names (first name, middle name, and surname) and sections of the date of birth (day, month, and year) to match records with possible data irregularities or missing data.

Statistical analysis

Two methods of analysis were used in this study: the 'standardised' and the 'comparative' method. Both methods involve three basic steps:

1. Tabulate the number of deaths/cancers for all groups (the exposed group, both comparison groups and each of the three categories in the exposed group). This report refers to these numbers as the observed (or actual) deaths/cancers.
2. Calculate the populations at risk for all years 1980 to 2004, by five year age groups, for all groups. These populations determine the expected number of deaths/cancers.
3. Divide the observed number of deaths/cancers by the expected number of deaths/cancers to obtain mortality/incidence.

The 'standardised' analysis

Standardised mortality ratios (SMR) and standardised cancer incidence ratios (SIR) were obtained for each combination of the exposed cohort (all exposed, Program 1, Program 2 and 'Other' program) and each of the comparison cohorts (Richmond and Amberley). This technique involves comparing the actual number of deaths (or cancers) to the expected number, and dividing the former figure by the latter. The expected number of deaths (or cancers) is derived by assuming the study cohort had the same mortality (or cancer incidence) as the Australian male population, controlling for age and year of death (or year of cancer diagnosis).

The 'comparative' analysis

Mortality rate ratios (MRR) and cancer incidence rate ratios (IRR) were calculated for each combination of exposed group (all exposed, Program 1 and Program 2) and comparison group (Richmond and Amberley). This technique involves dividing the observed/expected ratio of selected exposed group by the observed/expected ratio of the selected comparison group to obtain a relative rate (RR). The expected number of deaths (or cancer incidence) is derived by assuming that each of the two cohorts being compared had the mortality (or cancer incidence) of the two groups combined, controlling for age and year of death (or year of cancer diagnosis).

Confidence intervals

On their own, the SMR/SIR/RR are not sufficient to say whether the exposed groups experienced significantly higher or lower rates of mortality/cancer than might be expected, because differences may arise by chance. Where the SMR/SIR/RR are not equal to 1.0 (that is, there is a difference between the two groups) and the confidence interval does not include the value 1.0, only then can the difference be termed statistically significant.

This report uses the usual 95% confidence level. Confidence intervals were calculated using the asymptotic method, except where the number of deaths/cancers was less than or equal to 20, when the exact method was used.

Statistical power

In addition to SMR/SIR/RR and confidence intervals (CI), a third factor, statistical power, is important in assessing the results of the study. The power of a study is the probability that the study will detect a statistically significant difference between two study groups if the groups truly differ. This probability depends on the size of the effect, the incidence of the outcome and the number of observations or participants in the study. If an outcome of interest (that is, a specific cause of cancer incidence or mortality) is rare then even a large study may not have sufficient power to detect a true difference, especially if this difference is small. Conversely, if an event is very common or the difference between the groups is very large, then a smaller study will give a statistically significant result.

Multiple comparisons

The role of chance and the concept of multiple comparisons must also be considered when interpreting the results. By convention statistical significance is at the 95% level, which means there is up to a one in twenty probability the result could be due to chance. Over 50 specific cancer diagnoses or causes of death are reported in this study. Thus by definition, apparently statistically significant associations could arise for up to 2-3 cancers or causes of death by chance alone.

Additional analysis

The study team was concerned that a bias existed as a result of the process that identified DSRS personnel. In essence, the concern was that those who may have died prior to 1999 (when health concerns were raised, were less likely to have been identified as ever working in the DSRS programs and therefore were not included in the study group.

As the exposed cohorts were identified in 1999, a study looking at mortality since 1999 does not have this bias and is expected to yield more meaningful results. Unfortunately, analysis of data from 1999 has fewer years of follow-up and the confidence intervals around the point estimates are therefore much wider compared with the main analysis.

Future studies will enable the monitoring of trends in the health effects of the earlier programs, and take into account the younger participants who have not yet exhibited any health effects and may not for several decades.

Appendix 2: Statistical tables

Table A2.1: Observed and expected number of cancers for all exposed personnel and the standardised incidence ratio (SIR), 1982–2003

Cancer type	Observed	Expected	SIR	95% CI
All cancers^(a)	40	28	1.44	0.99–1.88
Brain	0	1	0.00	0.00–4.12
Breast	1	0	19.48	0.49–108.60
Connective soft tissue	0	0	—	—
Eye	1	0	7.62	0.19–42.46
Gastrointestinal	6	4	1.52	0.56–3.31
Colorectal	6	3	1.86	0.68–4.05
Stomach	0	1	0.00	0.00–5.87
Genitourinary	7	6	1.17	0.47–2.40
Bladder	0	1	0.00	0.00–5.79
Kidney	0	1	0.00	0.00–4.27
Prostate	5	5	0.96	0.31–2.23
Head and neck	1	1	0.91	0.02–5.09
Larynx	0	0	—	—
Lip	4	1	*4.13	1.12–10.56
Liver	0	0	—	—
Lung	4	2	1.97	0.54–5.04
Lymphoid and haematopoietic	4	3	1.23	0.34–3.15
Leukaemia	1	1	1.11	0.03–6.20
Lymphoid leukaemia	0	0	—	—
Myeloid leukaemia	1	0	2.10	0.05–11.70
Lymphoma	3	2	1.46	0.30–4.26
Hodgkin's disease	0	0	—	—
NHL ^(b)	3	2	1.83	0.38–5.36
Multiple myeloma	0	0	—	—
Melanoma	10	6	1.76	0.84–3.23
Pancreas	0	0	—	—
Unknown	2	1	2.68	0.32–9.67

* Findings statistically significant.

(a) Excludes non-melanocytic skin cancers.

(b) Non-Hodgkin lymphoma.

Table A2.2: Observed and expected number of cancers for Amberley personnel and the standardised incidence ratio (SIR), 1982–2003

Cancer type	Observed	Expected	SIR	95% CI
All cancers^(a)	302	300	1.01	0.89–1.12
Brain	5	8	0.60	0.19–1.40
Breast	0	1	0.00	0.00–6.40
Connective soft tissue	8	3	*2.52	1.12–4.97
Eye	1	1	0.79	0.02–4.42
Gastrointestinal	52	48	1.09	0.80–1.39
Colorectal	47	39	1.20	0.86–1.54
Stomach	5	7	0.68	0.22–1.60
Genitourinary	71	70	1.01	0.78–1.25
Bladder	6	8	0.77	0.28–1.67
Kidney	8	9	0.86	0.38–1.69
Prostate	47	68	*0.69	0.49–0.89
Head and neck	13	12	1.09	0.58–1.86
Larynx	8	4	1.98	0.88–3.90
Lip	8	9	0.89	0.39–1.75
Liver	2	3	0.61	0.07–2.19
Lung	27	27	1.00	0.62–1.38
Lymphoid and haematopoietic	25	32	0.79	0.48–1.10
Leukaemia	9	9	1.00	0.46–1.89
Lymphoid leukaemia	5	4	1.21	0.39–2.82
Myeloid leukaemia	4	5	0.88	0.24–2.26
Lymphoma	15	19	0.78	0.44–1.29
Hodgkin's disease	5	3	1.52	0.49–3.55
NHL ^(b)	10	16	0.63	0.30–1.16
Multiple myeloma	0	3	0.00	0.00–1.12
Melanoma	53	53	1.01	0.74–1.28
Pancreas	4	5	0.82	0.22–2.09
Unknown	6	9	0.69	0.25–1.50

* Findings statistically significant.

(a) Excludes non-melanocytic skin cancers.

(b) Non-Hodgkin lymphoma.

Table A2.3: Observed and expected number of cancers for Richmond personnel and the standardised incidence ratio (SIR), 1982–2003

Cancer type	Observed	Expected	SIR	95% CI
All cancers^(a)	290	297	0.98	0.86–1.09
Brain	16	9	1.73	0.99–2.81
Breast	0	1	0.00	0.00–6.63
Connective soft tissue	4	4	1.11	0.30–2.85
Eye	3	1	2.21	0.46–6.45
Gastrointestinal	38	43	0.88	0.60–1.16
Colorectal	30	35	0.85	0.54–1.15
Stomach	7	7	1.02	0.41–2.10
Genitourinary	72	65	1.10	0.85–1.36
Bladder	6	7	0.85	0.31–1.85
Kidney	9	9	0.98	0.45–1.86
Prostate	36	58	*0.62	0.42–0.82
Head and neck	9	12	0.77	0.35–1.46
Larynx	2	4	0.57	0.07–2.05
Lip	6	10	0.60	0.22–1.31
Liver	1	3	0.31	0.01–1.73
Lung	15	23	0.65	0.36–1.07
Lymphoid and haematopoietic	32	34	0.95	0.62–1.27
Leukaemia	7	9	0.74	0.30–1.53
Lymphoid leukaemia	3	4	0.73	0.15–2.14
Myeloid leukaemia	4	5	0.81	0.22–2.07
Lymphoma	21	21	0.99	0.57–1.42
Hodgkin's disease	7	4	1.67	0.67–3.45
NHL ^(b)	14	17	0.82	0.45–1.38
Multiple myeloma	4	3	1.31	0.36–3.34
Melanoma	67	59	1.14	0.87–1.42
Pancreas	6	4	1.34	0.49–2.92
Unknown	8	8	0.98	0.44–1.94

* Findings statistically significant.

(a) Excludes non-melanocytic skin cancers.

(b) Non-Hodgkin lymphoma.

Table A2.4: Observed and expected number of cancers for Program 1 exposed personnel and the standardised incidence ratio (SIR), 1982–2003

Cancer type	Observed	Expected	SIR	95% CI
All cancers^(a)	26	18	1.48	0.91–2.05
Brain	0	1	0.00	0.00–7.05
Breast	1	0	29.47	0.75–164.27
Connective soft tissue	0	0	—	—
Eye	0	0	0.00	0.00–45.71
Gastrointestinal	4	3	1.50	0.41–3.83
Colorectal	4	2	1.83	0.50–4.69
Stomach	0	0	—	—
Genitourinary	4	4	1.04	0.28–2.66
Bladder	0	0	—	—
Kidney	0	1	0.00	0.00–6.54
Prostate	3	4	0.81	0.17–2.38
Head and neck	0	1	0.00	0.00–5.16
Larynx	0	0	—	—
Lip	2	1	3.50	0.42–12.65
Liver	0	0	0.00	0.00–18.71
Lung	4	1	2.79	0.76–7.15
Lymphoid and haematopoietic	2	2	1.03	0.12–3.71
Leukaemia	1	1	1.85	0.05–10.33
Lymphoid leukaemia	0	0	—	—
Myeloid leukaemia	1	0	3.63	0.09–20.25
Lymphoma	1	1	0.83	0.02–4.63
Hodgkin's disease	0	0	—	—
NHL ^(b)	1	1	1.01	0.03–5.61
Multiple myeloma	0	0	0.00	0.00–19.44
Melanoma	7	3	2.08	0.84–4.28
Pancreas	0	0	—	—
Unknown	2	0	4.04	0.49–14.58

* Findings statistically significant.

(a) Excludes non-melanocytic skin cancers.

(b) Non-Hodgkin lymphoma.

Table A2.5: Observed and expected number of cancers for Program 2 exposed personnel and the standardised incidence ratio (SIR), 1982–2003

Cancer type	Observed	Expected	SIR	95% CI
All cancers^(a)	11	8	1.38	0.69–2.46
Brain	0	0	—	—
Breast	0	0	—	—
Connective soft tissue	0	0	—	—
Eye	1	0	26.23	0.66–146.23
Gastrointestinal	0	1	0.00	0.00–3.41
Colorectal	0	1	0.00	0.00–4.18
Stomach	0	0	—	—
Genitourinary	4	2	2.32	0.63–5.93
Bladder	0	0	0.00	0.00–21.68
Kidney	0	0	—	—
Prostate	2	1	1.41	0.17–5.10
Head and neck	1	0	3.29	0.08–18.33
Larynx	0	0	—	—
Lip	1	0	3.46	0.09–19.30
Liver	0	0	—	—
Lung	0	1	0.00	0.00–6.89
Lymphoid and haematopoietic	1	1	1.04	0.03–5.78
Leukaemia	1	0	3.75	0.09–20.89
Lymphoid leukaemia	0	0	—	—
Myeloid leukaemia	1	0	6.92	0.18–38.57
Lymphoma	0	1	0.00	0.00–5.98
Hodgkin's disease	0	0	—	—
NHL ^(b)	0	0	—	—
Multiple myeloma	0	0	—	—
Melanoma	3	2	1.77	0.37–5.18
Pancreas	0	0	—	—
Unknown	0	0	—	—

* Findings statistically significant.

(a) Excludes non-melanocytic skin cancers.

(b) Non-Hodgkin lymphoma.

Table A2.6: Observed and expected number of cancers for 'Other' program exposed personnel and the standardised incidence ratio (SIR), 1982–2003

Cancer type	Observed	Expected	SIR	95% CI
All cancers^(a)	8	5	1.46	0.65–2.88
Brain	0	0	0.00	0.00–18.62
Breast	0	0	0.00	0.00–386.44
Connective soft tissue	0	0	0.00	0.00–46.30
Eye	0	0	0.00	0.00–135.91
Gastrointestinal	2	1	2.92	0.35–10.55
Colorectal	2	1	3.61	0.44–13.04
Stomach	0	0	0.00	0.00–33.20
Genitourinary	1	1	0.88	0.02–4.92
Bladder	0	0	0.00	0.00–34.01
Kidney	0	0	0.00	0.00–22.77
Prostate	1	1	1.22	0.03–6.82
Head and neck	0	0	0.00	0.00–18.02
Larynx	0	0	0.00	0.00–72.20
Lip	1	5	0.21	0.01–1.18
Liver	0	0	0.00	0.00–63.60
Lung	0	0	0.00	0.00–11.40
Lymphoid and haematopoietic	2	1	2.87	0.35–10.37
Leukaemia	0	0	0.00	0.00–19.34
Lymphoid leukaemia	0	0	0.00	0.00–48.11
Myeloid leukaemia	0	0	0.00	0.00–34.58
Lymphoma	2	0	4.41	0.53–15.92
Hodgkin's disease	0	0	0.00	0.00–33.49
NHL ^(b)	2	0	5.82	0.70–21.03
Multiple myeloma	0	0	0.00	0.00–73.94
Melanoma	2	1	1.60	0.19–5.80
Pancreas	0	0	0.00	0.00–53.00
Unknown	0	0	0.00	0.00–27.21

* Findings statistically significant.

(a) Excludes non-melanocytic skin cancers.

(b) Non-Hodgkin lymphoma.

Table A2.7: Observed and expected number of deaths for all exposed personnel and the standardised mortality ratio (SMR), 1980–2004 and 1999–2004

Cause of death	1980–2004				1999–2004			
	Ob	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI
All deaths	16	38	*0.42	0.24–0.69	13	14	0.91	0.49–1.56
Infectious and parasitic	1	1	1.41	0.04–7.84	1	0	3.32	0.08–18.52
Neoplasms	9	9	0.96	0.44–1.82	7	5	1.52	0.61–3.12
Colorectal	2	1	1.79	0.22–6.45	1	1	1.79	0.05–9.99
Head and neck	0	0	—	—	0	0	—	—
Leukaemia	0	0	—	—	0	0	—	—
Lung	3	2	1.68	0.35–4.92	2	1	2.09	0.25–7.55
Melanoma	0	1	0.00	0.00–5.70	0	0	—	—
NHL ^(a)	2	1	3.76	0.45–13.58	2	0	*9.67	1.17–34.92
Prostate	0	0	—	—	0	0	—	—
Blood and blood organs	0	0	—	—	0	0	—	—
Endocrine nutritional and metabolic	0	1	0.00	0.00–4.31	0	0	—	—
Mental disorders	1	1	0.82	0.02–4.59	1	0	3.54	0.09–19.73
Nervous system	0	1	0.00	0.00–4.35	0	0	—	—
Circulatory system	2	8	*0.26	0.03–0.92	1	3	0.29	0.01–1.61
Ischaemic heart disease	1	5	0.19	0.00–1.08	0	2	0.00	0.00–1.60
Cerebrovascular	0	1	0.00	0.00–3.54	0	0	0.00	0.00–8.29
Respiratory system	0	1	0.00	0.00–3.22	0	1	0.00	0.00–7.06
COPD ^(b)	0	0	—	—	0	0	—	—
Digestive system	2	2	1.31	0.16–4.74	2	1	2.98	0.36–10.78
Liver, gall bladder, bile ducts	1	1	0.85	0.02–4.74	1	1	1.93	0.05–10.77
Alcoholic liver disease	1	1	1.20	0.03–6.70	1	0	2.78	0.07–15.51
Genitourinary system	0	0	—	—	0	0	—	—
External causes	1	13	*0.08	0.00–0.43	1	3	0.31	0.01–1.74
Assault	0	1	0.00	0.00–6.62	0	0	—	—
Motor vehicle accidents	0	4	*0.00	0.00–0.93	0	1	0.00	0.00–5.66
Suicide	1	5	0.21	0.01–1.16	1	1	0.74	0.02–4.13

* Findings statistically significant.

(a) Non-Hodgkin lymphoma.

(b) Chronic obstructive pulmonary disease.

Table A2.8: Observed and expected number of deaths for Amberley personnel and the standardised mortality ratio (SMR), 1980–2004 and 1999–2004

Cause of death	1980–2004				1999–2004			
	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI
All deaths	263	375	*0.70	0.62–0.79	113	149	*0.76	0.62–0.90
Infectious and parasitic	2	6	0.33	0.04–1.20	1	3	0.38	0.01–2.13
Neoplasms	95	110	0.86	0.69–1.04	50	53	0.95	0.69–1.21
Colorectal	18	14	1.28	0.76–2.02	8	7	1.22	0.54–2.40
Head and neck	2	4	0.50	0.06–1.80	1	2	0.57	0.01–3.17
Leukaemia	6	5	1.27	0.47–2.76	1	2	0.51	0.01–2.87
Lung	20	24	0.84	0.51–1.29	13	12	1.11	0.59–1.89
Melanoma	4	6	0.63	0.17–1.62	3	3	1.16	0.24–3.39
NHL ^(a)	2	6	0.36	0.04–1.30	1	2	0.45	0.01–2.49
Prostate	8	4	1.98	0.88–3.89	7	3	*2.68	1.08–5.52
Blood and blood organs	1	1	1.11	0.03–6.18	0	0	—	—
Endocrine nutritional and metabolic	10	9	1.05	0.51–1.94	5	5	1.01	0.33–2.36
Mental disorders	2	9	*0.22	0.03–0.78	0	3	0.00	0.00–1.45
Nervous system	6	8	0.76	0.28–1.65	2	4	0.55	0.07–1.99
Circulatory system	68	93	*0.73	0.56–0.91	31	38	0.81	0.53–1.10
Ischaemic heart disease	47	63	*0.75	0.53–0.96	17	26	0.67	0.39–1.07
Cerebrovascular	8	12	0.66	0.29–1.30	6	5	1.17	0.43–2.56
Respiratory system	13	14	0.94	0.50–1.60	7	7	1.07	0.43–2.21
COPD ^(b)	6	6	0.95	0.35–2.07	4	3	1.17	0.32–2.99
Digestive system	9	16	0.56	0.26–1.07	4	7	0.61	0.17–1.57
Liver, gall bladder, bile ducts	5	12	*0.41	0.13–0.96	1	5	0.20	0.01–1.14
Alcoholic liver disease	4	8	0.47	0.13–1.21	1	3	0.30	0.01–1.69
Genitourinary system	1	2	0.54	0.01–2.99	1	1	1.08	0.03–6.01
External causes	55	97	*0.57	0.42–0.72	12	27	*0.44	0.23–0.77
Assault	1	4	0.24	0.01–1.31	0	1	0.00	0.00–3.44
Motor vehicle accidents	18	28	0.65	0.38–1.02	4	6	0.70	0.19–1.78
Suicide	24	37	*0.65	0.39–0.91	5	11	0.45	0.14–1.04

* Findings statistically significant.

(a) Non-Hodgkin lymphoma.

(b) Chronic obstructive pulmonary disease.

Table A2.9: Observed and expected number of deaths for Richmond personnel and the standardised mortality ratio (SMR), 1980–2004 and 1999–2004

Cause of death	1980–2004				1999–2004			
	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI
All deaths	279	395	*0.71	0.62–0.79	93	153	*0.61	0.48–0.73
Infectious and parasitic	0	7	*0.00	0.00–0.52	0	3	0.00	0.00–1.20
Neoplasms	90	103	0.87	0.69–1.06	36	50	*0.73	0.49–0.97
Colorectal	10	12	0.81	0.38–1.48	3	6	0.50	0.10–1.46
Head and neck	2	4	0.54	0.07–1.95	0	2	0.00	0.00–2.16
Leukaemia	4	5	0.81	0.22–2.07	0	2	0.00	0.00–1.93
Lung	14	20	0.69	0.38–1.15	5	10	0.48	0.16–1.12
Melanoma	7	7	1.05	0.42–2.14	3	3	1.10	0.23–3.20
NHL ^(a)	4	6	0.72	0.19–1.82	2	2	0.91	0.11–3.27
Prostate	6	3	1.86	0.68–4.02	2	2	0.95	0.11–3.40
Blood and blood organs	1	1	1.04	0.03–5.73	1	0	2.13	0.05–11.79
Endocrine nutritional and metabolic	4	9	0.44	0.12–1.11	1	5	0.21	0.01–1.17
Mental disorders	2	12	*0.17	0.02–0.60	0	3	0.00	0.00–1.22
Nervous system	4	9	0.46	0.12–1.17	2	4	0.53	0.06–1.88
Circulatory system	57	87	*0.66	0.49–0.83	22	37	*0.60	0.35–0.85
Ischaemic heart disease	34	58	*0.59	0.39–0.79	11	25	*0.45	0.22–0.80
Cerebrovascular	10	12	0.87	0.42–1.60	4	5	0.83	0.22–2.10
Respiratory system	5	13	*0.39	0.13–0.91	3	6	0.51	0.11–1.49
COPD ^(b)	2	5	0.39	0.05–1.41	1	3	0.36	0.01–1.99
Digestive system	6	16	*0.37	0.14–0.81	2	7	0.29	0.03–1.04
Liver, gall bladder, bile ducts	3	12	*0.24	0.05–0.71	1	5	0.19	0.00–1.05
Alcoholic liver disease	3	9	0.35	0.07–1.01	1	4	0.28	0.01–1.53
Genitourinary system	1	2	0.56	0.01–3.09	1	1	1.14	0.03–6.28
External causes	107	124	0.86	0.70–1.02	24	35	*0.70	0.42–0.98
Assault	0	5	*0.00	0.00–0.67	0	1	0.00	0.00–2.65
Motor vehicle accidents	37	37	1.02	0.69–1.35	7	7	0.98	0.39–2.01
Suicide	44	48	0.93	0.66–1.20	13	14	0.91	0.48–1.54

* Findings statistically significant.

(a) Non-Hodgkin lymphoma.

(b) Chronic obstructive pulmonary disease.

Table A2.10: Observed and expected numbers of deaths for Program 1 exposed personnel and the standardised mortality ratio (SMR), 1980–2004 and 1999–2004

Cause of death	1980–2004				1999–2004			
	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI
All deaths	9	23	*0.40	0.18–0.75	7	8	0.85	0.34–1.75
Infectious and parasitic	1	0	2.57	0.06–14.31	1	0	6.20	0.16–34.58
Neoplasms	5	6	0.80	0.26–1.86	4	3	1.33	0.36–3.40
Colorectal	0	1	0.00	0.00–4.79	0	0	0.00	0.00–9.91
Head and neck	0	0	0.00	0.00–15.94	0	0	0.00	0.00–34.62
Leukaemia	0	0	0.00	0.00–12.74	0	0	0.00	0.00–35.47
Lung	3	1	2.37	0.49–6.94	2	1	3.04	0.37–10.99
Melanoma	0	0	—	—	0	0	—	—
NHL ^(a)	1	0	2.96	0.07–16.50	1	0	7.80	0.20–43.47
Prostate	0	0	0.00	0.00–18.68	0	0	0.00	0.00–27.64
Blood and blood organs	0	0	0.00	0.00–67.59	0	0	0.00	0.0–148.67
Endocrine nutritional and metabolic	0	1	0.00	0.00–6.73	0	0	0.00	0.00–13.26
Mental disorders	1	1	1.66	0.04–9.28	1	0	7.72	0.20–43.05
Nervous system	0	0	0.00	0.00–7.49	0	0	0.00	0.00–18.29
Circulatory system	2	5	0.38	0.05–1.38	1	2	0.46	0.01–2.54
Ischaemic heart disease	1	4	0.28	0.01–1.58	0	1	0.00	0.00–2.48
Cerebrovascular	0	1	0.00	0.00–5.31	0	0	0.00	0.00–12.92
Respiratory system	0	1	0.00	0.00–4.85	0	0	0.00	0.00–10.78
COPD ^(b)	0	0	0.00	0.00–12.10	0	0	0.00	0.00–21.32
Digestive system	0	1	0.00	0.00–3.70	0	0	0.00	0.00–9.00
Liver, gall bladder, bile ducts	0	1	0.00	0.00–4.80	0	0	0.00	0.00–11.72
Alcoholic liver disease	0	1	0.00	0.00–6.82	0	0	0.00	0.00–17.01
Genitourinary system	0	0	0.00	0.00–34.60	0	0	0.00	0.00–73.02
External causes	0	7	*0.00	0.00–0.56	0	1	0.00	0.00–2.83
Assault	0	0	0.00	0.00–12.85	0	0	0.00	0.00–71.38
Motor vehicle accidents	0	2	0.00	0.00–1.75	0	0	0.00	0.00–14.45
Suicide	0	2	0.00	0.00–1.53	0	1	0.00	0.00–6.69

* Findings statistically significant.

(a) Non-Hodgkin lymphoma.

(b) Chronic obstructive pulmonary disease.

Table A2.11: Observed and expected numbers of deaths for Program 2 exposed personnel and the standardised mortality ratio (SMR), 1980–2004 and 1999–2004

Cause of death	1980–2004				1999–2004			
	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI
All deaths	3	11	0.27	*0.06–0.79	3	4	0.69	0.14–2.03
Infectious and parasitic	1	0	4.57	0.12–25.46	1	0	10.69	0.27–59.58
Neoplasms	0	3	0.00	0.00–1.44	0	1	0.00	0.00–2.84
Colorectal	0	0	—	—	0	0	—	—
Head and neck	0	0	—	—	0	0	—	—
Leukaemia	0	0	—	—	0	0	—	—
Lung	0	0	—	—	0	0	—	—
Melanoma	0	0	—	—	0	0	—	—
NHL ^(a)	0	0	—	—	0	0	—	—
Prostate	0	0	—	—	0	0	—	—
Blood and blood organs	0	0	—	—	0	0	—	—
Endocrine nutritional and metabolic	0	0	—	—	0	0	—	—
Mental disorders	0	0	—	—	0	0	—	—
Nervous system	0	0	—	—	0	0	—	—
Circulatory system	0	2	0.00	0.00–1.76	0	1	0.00	0.00–3.79
Ischaemic heart disease	0	1	0.00	0.00–2.71	0	1	0.00	0.00–5.71
Cerebrovascular	0	0	—	—	0	0	—	—
Respiratory system	0	0	—	—	0	0	—	—
COPD ^(b)	0	0	—	—	0	0	—	—
Digestive system	1	0	2.41	0.06–13.44	1	0	5.18	0.13–28.89
Liver, gall bladder, bile ducts	0	0	—	—	0	0	—	—
Alcoholic liver disease	0	0	—	—	0	0	—	—
Genitourinary system	0	0	—	—	0	0	—	—
External causes	1	4	0.24	0.01–1.35	1	1	0.87	0.02–4.83
Assault	0	0	—	—	0	0	—	—
Motor vehicle accidents	0	1	0.00	0.00–2.96	0	0	—	—
Suicide	1	2	0.63	0.02–3.52	1	0	2.05	0.05–11.44

* Findings statistically significant.

(a) Non-Hodgkin lymphoma.

(b) Chronic obstructive pulmonary disease.

Table A2.12: Observed and expected numbers of deaths for 'Other' program exposed personnel and the standardised mortality ratio (SMR), 1980–2004 and 1999–2004

Cause of death	1980–2004				1999–2004			
	Obs	Exp	SMR	95% CI	Obs	Exp	SMR	95% CI
All deaths	4	8	0.50	0.14–1.27	3	3	0.94	0.19–2.75
Infectious and parasitic	0	0	—	—	0	0	—	—
Neoplasms	3	2	1.79	0.37–5.22	2	1	2.32	0.28–8.39
Colorectal	2	0	10.69	1.29–38.62	1	0	10.12	0.26–56.41
Head and neck	0	0	—	—	0	0	—	—
Leukaemia	0	0	—	—	0	0	—	—
Lung	0	0	—	—	0	0	—	—
Melanoma	0	0	—	—	0	0	—	—
NHL ^(a)	1	0	9.57	0.24–53.35	1	0	23.78	0.6–132.58
Prostate	0	0	—	—	0	0	—	—
Blood and blood organs	0	0	—	—	0	0	—	—
Endocrine nutritional and metabolic	0	0	—	—	0	0	—	—
Mental disorders	0	0	—	—	0	0	—	—
Nervous system	0	0	—	—	0	0	—	—
Circulatory system	0	1	—	—	0	1	0.00	0.00–5.45
Ischaemic heart disease	0	1	—	—	0	0	—	—
Cerebrovascular	0	0	—	—	0	0	—	—
Respiratory system	0	0	—	—	0	0	—	—
COPD ^(b)	0	0	—	—	0	0	—	—
Digestive system	1	0	3.45	0.09–19.24	1	0	7.10	0.18–39.60
Liver, gall bladder, bile ducts	1	0	4.48	0.11–24.99	1	0	9.10	0.23–50.74
Alcoholic liver disease	1	0	6.30	0.16–35.10	1	0	12.95	0.33–72.18
Genitourinary system	0	0	—	—	0	0	—	—
External causes	0	3	0.00	0.00–1.12	0	1	0.00	0.00–3.74
Assault	0	0	—	—	0	0	—	—
Motor vehicle accidents	0	1	0.00	0.00–3.68	0	0	—	—
Suicide	0	1	0.00	0.00–2.93	0	0	—	—

* Findings statistically significant.

(a) Non-Hodgkin lymphoma.

(b) Chronic obstructive pulmonary disease.

Table A2.13: Observed and expected numbers of cancers and deaths, and relative rate (RR), for Program 1 exposed personnel and Amberley comparison group, selected periods 1980–2004

Cancer/cause of death	Program 1 exposed		Amberley		RR	95% CI
	Observed	Expected	Observed	Expected		
All cancers ^{(a)(b)}	26	18	302	310	1.47	0.94–2.19
Colorectal	4	3	47	48	1.51	0.39–4.13
Lung	4	2	27	29	2.57	0.65–7.37
Lymphoid/haematopoietic	2	1	25	26	1.43	0.16–5.75
Melanoma	7	3	53	57	2.16	0.83–4.77
Prostate	3	2	47	48	1.29	0.26–4.02
All deaths 1980–2004	9	15	263	257	0.57	0.26–1.10
All neoplasm deaths 1980–2004	5	5	95	95	0.98	0.31–2.37
All deaths 1999–2004	7	6	113	114	1.13	0.44–2.41
All neoplasm deaths 1999–2004	4	3	50	51	1.49	0.39–4.07

(a) Excludes non-melanocytic skin cancers.

(b) All cancer incidences relate to the period 1982–2003.

Table A2.14: Observed and expected number of cancers and deaths, and relative rate (RR), for Program 2 exposed personnel and Amberley comparison group, selected periods 1980–2004

Cancer/cause of death	Program 2 exposed		Amberley		RR	95% CI
	Observed	Expected	Observed	Expected		
All cancers ^{(a)(b)}	11	8	302	305	1.37	0.67–2.48
Colorectal	0	1	47	46	—	—
Lung	0	1	27	26	—	—
Lymphoid/haematopoietic	1	1	25	25	1.27	0.03–7.75
Melanoma	3	2	53	54	1.57	0.31–4.85
Prostate	2	1	47	48	2.47	0.29–9.42
All deaths 1980–2004	3	7	263	259	0.44	0.09–1.30
All neoplasm deaths 1980–2004	1	2	95	94	0.45	0.01–2.56
All deaths 1999–2004	3	3	113	113	1.04	0.21–3.11
All neoplasm deaths 1999–2004	1	1	50	50	0.80	0.02–4.67

(a) Excludes non-melanocytic skin cancers.

(b) All cancer incidences relate to the period 1982–2003.

Table A2.15: Observed and expected number of cancers and deaths, and relative rate (RR), for Program 1 exposed personnel and Richmond comparison group, selected periods 1980–2004

Cancer/cause of death	Program 1 exposed		Richmond		RR	95% CI
	Observed	Expected	Observed	Expected		
All cancers ^{(a)(b)}	26	17	290	299	1.54	0.99–2.30
Colorectal	4	2	30	32	2.12	0.54–6.00
Lung	4	1	15	18	3.82	0.92–12.0
Lymphoid/haematopoietic	2	2	32	32	1.10	0.13–4.30
Melanoma	7	4	67	70	1.98	0.77–4.31
Prostate	3	2	36	37	1.32	0.26–4.19
All deaths 1980–2004	9	16	279	272	0.54	0.24–1.04
All neoplasm deaths 1980–2004	5	5	89	89	0.91	0.29–2.21
All deaths 1999–2004	7	6	93	94	1.25	0.49–2.68
All neoplasm deaths 1999–2004	4	2	36	38	1.85	0.48–5.15

(a) Excludes non-melanocytic skin cancers.

(b) All cancer incidences relate to the period 1982–2003.

Table A2.16: Observed and expected number of cancers and deaths, and relative rate (RR), for Program 2 exposed personnel and Richmond comparison group, selected periods 1980–2004

Cancer/cause of death	Program 2 exposed		Richmond		RR	95% CI
	Observed	Expected	Observed	Expected		
All cancers ^{(a)(b)}	11	8	290	293	1.41	0.69–2.55
Colorectal	0	1	30	29	—	—
Lung	0	0	15	15	—	—
Lymphoid/haematopoietic	1	1	32	32	1.11	0.03–6.65
Melanoma	3	2	67	68	1.52	0.31–4.63
Prostate	2	1	36	37	2.40	0.28–9.31
All deaths 1980–2004	3	7	279	275	0.40	0.08–1.17
All neoplasm deaths 1980–2004	1	2	89	88	0.47	0.01–2.71
All deaths 1999–2004	3	2	93	94	1.23	0.25–3.72
All neoplasm deaths 1999–2004	1	1	36	36	1.20	0.03–7.11

(a) Excludes non-melanocytic skin cancers.

(b) All cancer incidences relate to the period 1982–2003.

Table A2.17: Investigated cancers and causes of death with corresponding ICD-10 codes

Cancer type/cause of death	ICD-10 codes
All neoplasms	C00–D48
All cancers ^(a)	C00–C43, C45–C97
Brain	C70–C72
Breast	C50
Connective soft tissue	C47–C49
Eye	C69
Gastrointestinal	C16–C21
Colorectal	C18–C21
Stomach	C16
Genitourinary	C60–C68
Bladder	C67
Kidney	C64
Prostate	C61
Head and neck	C01–C14
Larynx	C32
Lip	C00
Liver	C22
Lung	C33–C34
Lymphoid and haematopoietic	C81–C96
Leukaemia	C91–C95
Lymphoid leukaemia	C91
Myeloid leukaemia	C92
Lymphoma	C81–C85, C96
Hodgkin's disease	C81
NHL	C82–C85, C96
Multiple myeloma	C90
Melanoma	C43
Pancreas	C25
Unknown	C26, C39, C76–C80
Infectious and parasitic	A00–B99
Blood and blood organs	D50–D59
Endocrine, nutritional and metabolic	E00–E90
Mental disorders	F00–F99
Nervous system	G00–G99
Circulatory system	I00–I99
Ischaemic	I20–I25
Cerebrovascular	I60–I69
Respiratory system	J00–J99
COPD	J41–J44
Digestive system	K00–K93
Liver, gall bladder, bile ducts	K70–K83

(a) Excludes non-melanocytic skin cancers.

Glossary

Confidence Interval (CI) A statistical term describing a range (interval) of values within which we can be 'confident' that the true value lies, usually because it has a 95% or higher chance of doing so.

Epidemiology The study of the patterns and causes of health and disease in population and the application of this study to improve health.

F-111 An aircraft manufactured by General Dynamics, purchased by the Royal Australian Air Force from the United States. The aircraft has two crew, and is an all-weather strike, reconnaissance and bomber aircraft.

Incidence See *New cancer case*.

New cancer case A person who has a new cancer diagnosed for the first time. A person may have more than one cancer and therefore may be counted twice in incidence statistics if it is decided that the two cancers are not of the same origin. This is based on a series of principles called the 'multiple primary rules'.

'Other' programs The third DSRS group examined in the current study comprising the Wings Program and Spray Seal Program.

Program 1 The first of the DSRS programs which were undertaken over three decades (1977–1999). Program 1 was a fuselage program at Amberley RAAF Base ran from October 1977 to December 1982.

Program 2 The second of the DSRS programs which were undertaken over three decades (1977–1999). Program 2 was also a fuselage program that ran from February 1990 to August 1993.

Spray Seal Program The Spray Seal program was part of the DSRS programs which were undertaken over three decades (1977–1999). The Spray Seal Program ran from March 1996 to November 1999.

Unit Inquiry Now referred to as a Routine Inquiry, can be an inquiry into a broad range of matters, which arise in a unit from day to day. These inquiries are conducted with as little formality as possible.

Wings Program The Wings program was part of the DSRS programs which were undertaken over three decades (1977–1999). The Wings Program ran from August 1985 to June 1992.

References

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SHOAMP reports are also available on the internet at:

<http://www.defence.gov.au/health/research/shoamp/i-SHOAMP.htm>