Health Consultation

Past Air Emissions

Kelly Air Force Base

San Antonio, Bexar County, Texas

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Prepared by

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Forward

ATSDR was requested to evaluate potential exposure to past air emissions. To fulfill this request, ATSDR gathered relevant data and information to reconstruct potential past inhalation exposures. The available information from industrial activities and aircraft emissions was often scarce or non-existent. To provide the community and health officials with some perspective on potential past exposures, ATSDR performed a dose reconstruction by modeling the available information. ATSDR recognizes the estimates provided have a varying degree of uncertainty and caution should be exercised in the application of the estimates. This document describes the information used to estimate the exposures to past air emissions from Kelly Air Force Base. Recommendations are also included that provide public health follow-up activities that ATSDR considers prudent based on the results of the modeling effort and ATSDR's public health evaluation.

Information in this document is organized to improve readability by the public by placing methodology and scientific details in appendixes. The main body of the document contains the summary of the public health evaluation with supporting information contained in the appendixes.

Summary

ATSDR completed Phase I of the public health assessment (PHA) of Kelly Air Force Base (AFB) in August 1999 [1]. In Phase I, ATSDR recommended further investigation of potential exposures to past air emissions to be performed during Phase II. This health consultation is a part of Phase II and reports the evaluation of potential past exposures to air emissions from activities at Kelly AFB (see Table 1). This report was revised in January 2004 based on external peer review comments (see Appendix D for comments and responses).

Findings: *Off-base exposures to estimates of individual contaminant levels of hazardous air pollutants (HAPs) from **stationary** source emissions were unlikely to have resulted in adverse health effects and present **no apparent health hazard**. Data from past hexavalent chromium air emissions (before 1980) were insufficient to assess public health implications and represent an **indeterminate health hazard**.*

*Off-base exposures to estimates of individual contaminant levels from **aircraft** emissions were unlikely to have resulted in adverse health effects and present **no apparent health hazard.***

*The uncertainty in potential interactions from off-base exposure to chemical mixtures from stationary and aircraft emissions represents an **indeterminate health hazard**.*

Data were unavailable to evaluate potential exposure to emissions from incineration of cyanide wastes and fuel emissions from misting.

These findings are based in part on emissions inventory data, estimated air concentrations from air dispersion modeling, and toxicological data. The uncertainties of these data are discussed in this report and considered in these findings.

Table 1

Exposure Pathway Elements								
Pathway	**Contaminants**	**Source**	**Environmental Media**	**Point of Exposure**	**Route of Exposure**	**Exposed Population**	**Time**	**Comments**
Air	Benzene 1,3-Butadiene Formaldehyde	Stationary Sources and Aircraft Emissions	Ambient Air	Off Base	Inhalation	Adult/Child	Past (before 1995)	Indeterminate health hazard to cumulative exposures of chemical mixtures
Air	Hexavalent Chromium	Stationary Sources	Ambient Air	Off Base	Inhalation	Adult/Child	Past[a] (before 1980)	Indeterminate
Air	Hexavalent Chromium	Stationary Sources	Ambient Air	Off Base	Inhalation	Adult/Child	Past (1980 and later)	No Apparent Health Hazard
Air	Individual HAPs [b]	Stationary Sources	Ambient Air	Off Base	Inhalation	Adult/Child	Past (before 1995)	No Apparent Health Hazard
Air	Individual Contaminants in JP-4 Jet Fuel Exhaust	Aircraft Emissions	Ambient Air	Off Base	Inhalation	Adult/Child	Past (before 1995)	No Apparent Health Hazard.
Air	Fuels, HAPs	Stationary Sources and Aircraft Emissions	Ambient Air	On Base	Inhalation	Worker	Past	ATSDR does not evaluate worker exposures. Recommendations are made for investigation by others.

a. Hexavalent chromium was emitted from 5 plating shops. The most significant were located in Buildings 258/295 and Building 301. Buildings 258/259 began operation in 1942 and shutdown in 1977. Building 301 replaced Building 258/259 in 1977. The emission rates of hexavalent chromium from Building 258/259 are not known. The emission rates from Building 301 are based on stack tests completed in 1980. The time prior to the 1980 stack test is used to define past exposures because of the unknown emission rates from Building 301 prior to 1980 and unknown emission rates from Buildings 258/259.

b. Hazardous Air Pollutants - see text for discussion.

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Background

The late Congressman Frank Tejeda requested that ATSDR investigate the potential relationship between environmental contaminant releases from Kelly AFB and the adverse health effects reported by area residents north and southeast of the base [2]. ATSDR publicly released findings during Phase I on August 24, 1999, and also described activities to be performed during Phase II. During Phase I, ATSDR performed an air dispersion screening model of air emissions from stationary sources to estimate possible air contaminant concentrations in the community. ATSDR concluded there was no apparent public health hazard to the community from exposure to current air emissions (1995 and after). However, the available information was inadequate to evaluate the potential for health effects from exposures to *pas*t air emissions (before 1995).

ATSDR considers past air emissions to have been an important contributor to potential environmental contamination and past exposure because:

- pollution control measures were not closely regulated and pollution control may not have been routinely used,
- the use of toxic chemicals in the workplace was more prevalent because of the limited knowledge of environmental health effects, and
- JP-4 jet fuel was used until 1994 at Kelly AFB and contained an average benzene concentration greater than the benzene concentration of the currently used jet fuel, JP-8 [3].

The following issues related to past air emissions are addressed in this document:

Stationary source emissions

- stationary emissions from processes such as chromium plating, painting, and degreasing.
- incinerator emissions involving cyanide (requested by the community).

Aircraft activity emissions (from mobile sources)

- emissions during takeoff, landing, and taxi operations.
- the reported “misting” through the inefficient burning of jet fuels during and previous to the 1970s (reported by Kelly Air Force Base [4]).

Results and Discussion

How does ATSDR evaluate past air emissions?

- Available air emissions data are evaluated to determine the public health implications from potential exposures. The uncertainty in available data, air sampling, air dispersion modeling methodology, and exposure information may vary. These uncertainties result in a varying degree of confidence in the conclusions.

- Air quality sampling and analysis have only been generally available for the more *recent* past. For *distant* past air emissions, air dispersion modeling is an important tool available to estimate concentrations that may have been present in the community. Air dispersion modeling can estimate the location and concentration of air contaminants released by the source of interest. Air dispersion modeling can also differentiate emissions from the source of interest and emissions from other sources, such as other industrial sources and automobiles. Air dispersion modeling, as with ambient air monitoring, do not determine a persons exposure because of a person's movement throughout the day. Air concentrations from air dispersion modeling are considered estimates because they are calculated values using mathematical formulas representing the atmosphere. These calculations introduce some uncertainty which are considered in the evaluation. The uncertainty in the location of a predicted concentration is often higher then the actual value (i.e., models are good for determining the air concentrations, but not exact locations). Because of the lack meteorological and emissions detail, models are not good at determining short term episodic events.

- All available information is used to make conclusions about site-specific exposures. The estimated contaminant levels are compared to health-based comparison values derived by ATSDR, the Environmental Protection Agency, or state environmental and health agencies. Exposure to these levels would not be expected to result in adverse health effects, even for sensitive people in the general population. If an individual contaminant level does not exceed health-based comparison values, no further analysis of exposure to that individual contaminant is needed; however, the contaminants may be included when considering chemical mixtures or cumulative analysis. If a contaminant exceeds health-based comparison values, ATSDR performs further analysis including a risk analysis. Risk analysis is a multidimensional endeavor and may include a risk assessment, a toxicological evaluation, and an evaluation of health outcome data and epidemiological studies. Professional judgment is used to reach conclusions and make recommendations which may include follow-up activities such as health education, health studies, and public health interventions [5, 6].

How did ATSDR evaluate past air emissions at Kelly AFB?

ATSDR requested data from Kelly AFB for representative past air emissions, but routine sampling and analysis data of ambient air emissions were not available for the past era of concern. An air dispersion model of these emissions data estimated contaminant levels that may have been present in the community. Contaminants were selected for investigation by considering both toxicity and quantity used or emitted. Contaminants whose past use was similar to current use were not modeled during Phase II if the Phase I modeling did not suggest a public health concern and the source location or stack height were also similar. Appendix A addresses the air dispersion modeling methodology.

The modeling of aircraft emissions is a complex task. Many different aircraft must be considered as well as the numbers and types of engines used on specific aircraft. The engine efficiency, burn temperatures, and operating modes may be different for different types of engines, resulting in different emissions during operations such as taxi, take off, afterburn, approach, and landing. Emission estimates are further compounded by different flightline use in different years by different aircraft. Data were not available to complete the input values needed for this complexity of modeling. Therefore, ATSDR performed an air dispersion model on a worst-case scenario to estimate whether these emissions could be of public health concern. For the worst-case scenario, ATSDR selected these modeling inputs:

- the aircraft having the most engines,
- the least efficient engine for modeling of emissions,
- the engine with the highest emissions, and
- a year in which operations were the highest reported.

ATSDR also performed a dispersion model for a scenario representing planes with lower emissions. The modeling assumptions and specific model input parameters are provided in Appendix B.

ATSDR performed an air dispersion model using U.S. EPA's Industrial Source Complex Short Term Version 3 model (ISCST3) for both stationary source (industrial) and aircraft emissions. Both stationary and aircraft emissions were used to estimate individual contaminant levels and subsequent risk in the community. Contaminants with the highest estimated chronic risk (considering quantity and toxicity) were selected for evaluating chemical mixtures and cumulative exposures.

The ISCST3 model in flat terrain similar to Kelly Air Force Base has been shown to be accurate within two-times to one-half the actual result [7]. For instance, if the "real" value is 1 $\mu g/m^3$, the model could show a range of 2 $\mu g/m^3$ to 0.5 $\mu g/m^3$. The largest uncertainty in this study, though, is the emission data used in the model and which are not accounted for in this error range.

What did ATSDR find?

Data Acquisition

Information about stationary (industrial) emissions and incinerator emissions involving cyanide wastes was requested from Kelly AFB. In addition, information about issues related to aircraft emissions, including speciated aircraft emissions using JP-4 jet fuel and aircraft misting (as described by Kelly AFB) was requested.

In March 2000, Kelly AFB submitted a report containing data and information about stationary and aircraft emissions [8]. Clarification and explanation of these data and information was requested. Kelly AFB submitted additional explanation in June 2000 [9]. ATSDR requested further clarification and explanation of both the original (March 2000) and updated data and information (June 2000), which Kelly AFB submitted in December 2000 [10]. Kelly AFB reported that some of the data and information requested could not be located. The available data are not comprehensive and may not be representative of past air emissions.

Sufficient data were acquired for:

- stationary emissions (except for hexavalent chromium)
- aircraft emissions

Sufficient data were not acquired for:

- past air emissions of hexavalent chromium
- air emissions due to "misting"
- incinerator emissions involving cyanide wastes

Stationary Emissions

Industrial Sources

For industrial activities except chromium plating and cyanide incineration, the data supplied by Kelly AFB were sufficient for analysis and making conclusions. Data were provided for the following contaminants: tetrachloroethylene (PCE), hexavalent chromium, methylene chloride, methyl ethyl ketone, benzene, ethyl benzene, formaldehyde, toluene, xylene, styrene, naphthalene, acrolein, acetaldehyde, trichloroethylene (TCE), trichloroethane (TCA), and dichloroethane (see Appendix B, Attachment 1, for a listing of chemicals modeled, locations, and emission rates) [8]. ATSDR performed an air dispersion model of these emissions and found that the *annual average maximum off-base concentrations of most chemicals did not exceed health-based comparison values. No chemicals exceeded noncancer comparison values. The maximum off-base concentrations of two chemicals (PCE and methylene chloride) exceeded a cancer comparison value and required further analysis* (Appendix B, Table B-1). Hexavalent chromium data from plating operations were insufficient for evaluation. See Appendix B for more detail.

Using modeling and analysis, ATSDR concluded that estimated levels of individual contaminants in the community would not represent a public health hazard. However, insufficient data were provided for evaluation of hexavalent chromium.

Incineration of cyanide waste
Kelly AFB reported that the incinerator that burned cyanide waste operated for about a year, but never operated properly [11, 12]. Kelly AFB did not submit quantitative data regarding the incineration of cyanide waste. Therefore, insufficient information is available for a health evaluation of potential exposure to cyanide air emissions from incineration.

Aircraft Emissions

Speciated jet fuel emissions.
ATSDR requested speciated JP-4 jet fuel emissions data and aircraft operational information such as takeoffs, landings, and taxi activities. JP-4 jet fuel was used until 1994 when the base converted to JP-8 jet fuel [13]. JP-4 jet fuel may have contained 100 times more benzene than JP-8 jet fuel [3] Kelly AFB provided information on the speciation of emissions of JP-8 jet fuel and on volatile organic chemicals (VOCs), nitrogen-oxygen compounds (NOx), and sulfur-oxygen compounds (SOx). The speciation of fuel was important as speciation identifies the individual chemicals present, such as benzene, enabling ATSDR to perform evaluations on specific chemicals. The information on speciation of emissions from aircraft using JP-4 jet fuel acquired by ATSDR was difficult to find and may not be representative of specific aircraft emissions from Kelly AFB activities. Current and past operational data were provided by Kelly AFB and consisted of numbers of takeoffs and landings [14, 15]. Data on JP-4 jet fuel speciation acquired by ATSDR and operational data provided by Kelly AFB were used to conduct an air dispersion model of aircraft emissions. A worst-case jet fuel emissions scenario was used for modeling aircraft emissions. The Industrial Source Complex air dispersion model was used (ISCST3, see Appendix B for details).

The modeling scenario included 336,000 takeoff and landings per year of a B52 (which has eight engines) using the least efficient engine (TF33-3). This modeling effort identified a potential worst-case scenario that would overestimate emissions. To give some perspective of the conservative nature of this approach, ATSDR also modeled emissions from an F16 aircraft, which has only one engine. A B52 emits an estimated 16 times more 1,3-butadiene and 8 times more benzene than an F16 (with an F110 engine) during takeoff and landing operations [16]. The operational data used in the model were about 3 times the average operational data after 1973 (330,000 operations in 1964. See Appendix B, Figure B-1). Concentrations estimated by the air dispersion model were the annual averages of the maximum off-base concentrations. Benzene, 1,3-butadiene, and formaldehyde contributed the highest estimated risk (see Appendix B for discussion).

Estimated levels using a worst-case scenario indicated that past air emissions of individual contaminants from aircraft would not be cause for public health concern. See Appendix B for more detail.

Misting
During the Viet Nam years, area residents described frequently experiencing a mist of jet fuel which they attributed to fuel jettisoning. ATSDR evaluated fuel jettisoning during the Phase I

Public Health Assessment and found that the Air Force did not keep records of fuel jettisoning. A frequent experience of mist in the community would be unlikely if Air Force policy concerning fuel jettisoning were followed. Kelly AFB identified another potential cause for the jet fuel mist experienced by the community in comments to the Phase I PHA, as follows:

"The flight aircraft's of the 50's, 60's, and early 70's routinely sprayed minor droplets of unburned fuel on approach and departure ends of the runways. The engines were not as efficient as today's engines. The amount of the spray was small, but could have been noticed as a very fine mist. Further, C-5s were not actually deployed until 1973. Most unburned fuel evaporated shortly after being blown out of the tailpipe. This spray was usually attributed to aircraft using after-burns, as after-burners function by dropping large amounts of fuel in the burn basket. A minuscule amount of fuel does not burn completely" [4].

Kelly AFB personnel were unable to locate quantitative information on misting. Kelly AFB has prepared a qualitative assessment to address this issue [17]. (See Appendix B, Attachment 2). ATSDR's investigation indicates that the mist that residents recall may not have been due to "misting", as defined by the Kelly AFB comment. NASA and USAF scientists report that they have not encountered the above phenomena. Exhaust temperatures are in excess of 400 degrees Celsius, one meter behind the exit plume of an F-14 [18]. All fuel should be in the gaseous form at this temperature. Other possible reasons for misting are speculated to be caused by leaking fuel, improperly jettisoned fuel, fuel jettisoned during an emergency, or condensation.

Takeoff and landings during the 1960s have been reported to be greater than 300,000 operations per year, which would be equivalent to one operation every two minutes on a 24-hour basis [14]. (An operation is assumed here as one takeoff or one landing, and one touch and go maneuver is counted as two operations. This assumption is discussed in Appendix B). At this high rate of activity, it is conceivable that the combination of fuel leakage, inefficient burning, and improperly jettisoned fuel from individual aircraft could have a cumulative effect on ambient air quality, especially if the majority of operations were performed during daylight hours. However, the lack of data precludes a quantitative evaluation by ATSDR.

Cumulative Assessment and Chemical Mixing

The limited data from past air emissions from Kelly AFB are not adequate to address comprehensive cumulative risks because adequate data are not available on all contaminants. Nevertheless, ATSDR performed an assessment based on the available data and current scientific literature. Where appropriate, ATSDR assumed that available data were representative of past air emissions. The uncertainty in the limited available data, the air dispersion model, estimates of potential exposures, and the cumulative effects of chemical mixtures suggests little confidence in the comprehensiveness of such an effort.

Individuals come into contact with chemicals identified at Kelly AFB and other chemicals through non-site-related exposures in the environment, home, and workplace. An individual may be exposed to chemicals in many ways including in medicines, food, vehicle exhaust, alcohol, and drinking water. The total exposure that an individual experiences, as well as individual risk factors, determine if a person has health effects resulting from the exposures. The best cumulative

risk assessment given today's state of the science would fall short of being able to include an evaluation of the magnitude and interactions of *all* stressors and effects. At best, the risk estimates of a cumulative risk assessment will reflect *some* of the risks which may be reflected in community health statistics.

Exposure estimates of cumulative risks from aircraft and industrial emissions suggest a *moderate* cumulative risk for developing cancer if animal data are used and a *low* cumulative risk for developing cancer if human data are used exclusively (see Appendix C, Table C-1). ATSDR assigns a higher weight to well-designed and well-executed epidemiologic (human) studies than to animal studies of comparable quality in evaluating the potential human cancer risks. Epidemiological studies of occupational exposures suggest that exposures to 1,3-butadiene and benzene at air concentrations much higher than those estimated around Kelly AFB may be associated with the development of leukemia [19, 20]. However, workers are considered the healthiest segment of the general population. The levels at which other segments of the population might be effected is unknown. In addition, these occupational studies reported numbers of leukemia mortality (death) and not numbers of people developing the disease (incidence) or adverse health effects.

Formaldehyde has been associated with leukemia mortality in embalmers but not in industrial environments [21–24]. The differences in metabolism and mode of action does not suggest that formaldehyde would contribute to potential cumulative effects from exposures to benzene and 1,3-butadiene.

Through air dispersion modeling, ATSDR identified the community areas where exposure to the highest concentrations was most likely. Although not comprehensive, ATSDR can evaluate biologically plausible health outcome data to determine whether these health outcomes are occurring in this population at rates similar to or different from the general population. For some health outcomes, ATSDR further evaluated whether an association with an environmental exposure to air emissions from Kelly AFB was plausible (See ATSDR Health Outcome Data Evaluation Health Consultation [25]).

ATSDR investigated biologically plausible health outcome data in the 1999 Public Health Assessment [1]. Results of the investigation revealed some elevated health outcomes were not likely to be associated with an exposure to known contaminants from Kelly AFB. However, some elevated health outcomes could not be ruled out as having been associated with contaminants from Kelly AFB.

ATSDR concluded that some plausible cancer incidence rates (liver, kidney, lung, and leukemia) had been elevated in the ZIP Codes around Kelly during 1990 – 1994 as compared to the incidence rates found in the Hispanic population for the state of Texas [1].

Cancers usually involve a latency period - the period from the time of exposure or initiation until the onset and diagnosis of disease (generally 10–30 years, although some leukemia have been reported in as little as 3 years following exposure) [26]. Therefore, cancers reported during the time period examined (1990–1994) could have been the result of past exposures. Of the

biologically plausible cancers reported, leukemia is an outcome that ATSDR is continuing to investigate (see ATSDR Health Outcome Data Evaluation Health Consultation) [25]. The incidence of liver cancer was elevated throughout a large part of south Texas, and ATSDR is continuing to investigate liver cancer [25]. The areas around Kelly AFB that had an increased incidence of kidney and lung cancer did not correspond well with the areas where the highest air contaminant levels were predicted by air dispersion modeling.

Statistically significant elevations of leukemia in three ZIP Codes (1990–1994) have been reported by the Cancer Registry Division of the Texas Department of Health. Two of the ZIP Codes are in the predominant downwind direction and the third is off-base military housing. ATSDR has investigated the elevations and distribution of leukemia types in specific ZIP Codes (see ATSDR Health Outcome Data Health Consultation)[25]. Of the chemicals known to have been emitted by Kelly AFB, benzene and 1,3-butadiene are of concern because both have been associated with leukemia in epidemiological studies of workers and because the bone marrow is a target organ for both chemicals in animal studies [27–30](see Appendix C).

The limited available data are inadequate for conducting a comprehensive assessment of potential cumulative exposures to past air emissions. Assessments of available data do not indicate a public health concern but these data are incomplete and contain more uncertainty than data collected under regulatory agency oversight (e.g. State and Federal programs under the Clean Air Act). ***Because of the magnitude of uncertainty and because biologically plausible health outcomes were reported in areas where people may have been exposed, ATSDR concludes that further analysis of cancer health outcomes should be performed. This further analysis is found in the Health Outcome Data Evaluation Health Consultation*** [25]**.**

Susceptible Populations

ATSDR reports information on populations that may be of special interest and site-specific activities addressing potentially susceptible populations.

Children (Child Health Considerations)

Children may be at increased or decreased risk from chemical exposures. Factors that may affect their susceptibility include activity patterns, pharmacokinetic processes (ventilation rates, metabolism rates, and capacities), or pharmacodynamic processes (toxicant-target interactions in the immature hematopoietic system) [31].

Infants and children may be more vulnerable to leukemogenesis because the hematopoietic cell populations are differentiating and undergoing maturation. No data from human studies were found to indicate that children are more sensitive to benzene toxicity than are adults. Some studies have associated acute nonlymphocytic (myelocytic) leukemia and parental occupational exposures to benzene [32]. In children, the predominant type of leukemia is lymphocytic, while in adults, a combination of myeloid and lymphoid is predominately found [33]. Recent evidence suggests that *in utero* exposures may lead to leukemia [34].

Gender
No human exposure data were found to indicate that benzene affects human males and females differently.

Genetics
Individual risk factors influence an individual's unique tolerance or susceptibility to exposure and progression to disease. Polymorphisms are variations between individuals' genetic makeup which can result in changes in the way an individual responds to chemical exposures. While the genetic makeup of each individual is unknown, research indicates that certain variations in genetic makeup can account for differences in the way an individual responds to exposure to specific chemicals. Following are examples of research that illustrate the degree of variation that may exist in a population.

Individuals lacking an enzyme involved in the detoxification of a benzene metabolite could be susceptible to benzene toxicity. The lack of this enzyme appears to result from a true polymorphism in the NQO1 gene with a frequency of 13% in a reference population [35].

CYP2E1 activity in human hepatic microsomes has been shown to vary by 13-fold [36]. Differences in CYP2E1 between individual humans could indicate potential differential susceptibility to benzene and 1,3-butadiene toxicity.

Asthmatics
Individuals sensitive to respiratory irritants may experience respiratory effects at levels below where non-sensitive individuals experience respiratory effects.

Summary
While risk factors such as rates of genetic polymorphisms and asthma are not known for this population, developing hematopoietic systems may be more susceptible to insult from volatile organic compounds such as benzene and butadiene.

Conclusions and Recommendations

1. Individual contaminants from stationary sources.

Air dispersion modeling indicates that stationary source emissions were unlikely to have resulted in off-base exposures to individual chemicals at levels of public health concern and present *no apparent health hazard.*

Hexavalent chromium air emission data (before 1980) submitted by Kelly AFB are not sufficient for ATSDR to make a determination of public health significance and therefore represent an *indeterminate health hazard.*

Recommendation: Further investigate potential past air emissions of hexavalent chromium from Kelly AFB or include plausible health outcomes in the proposed mortality study (Kelly AFB Civilian Worker Mortality Study) to be conducted by the Kelly AFB Health Issues Working Group.

2. Individual contaminants from aircraft sources.

Air dispersion modeling indicates that aircraft emissions of JP-4 jet fuel were unlikely to have resulted in off-base exposures to individual chemicals at levels of public health concern and present *no apparent health hazard.*

3. Chemical mixtures from stationary and aircraft sources.

The uncertainty in potential interactions from exposure to the chemical mixture represents an *indeterminate health hazard.* Statistically significant elevations in leukemia have been previously reported in downwind ZIP Codes and off-base military housing.

Recommendation: Further investigation of elevated leukemia outcomes. This recommendation has been addressed by the Division of Health Studies, ATSDR, and reported in the Health Outcome Data Evaluation Health Consultation.

4. Air dispersion modeling sensitivity analysis suggests that selection of input parameters such as building height, building downwash, landscape type, and combinations of these parameters could result in higher estimates of on-base contaminant concentrations, but will not affect off-base concentrations. These conclusions are based in part on emissions inventory data and estimated air concentrations from air dispersion modeling. The uncertainties of these data are discussed in this report and considered in these conclusions.

Recommendation: Consider biologically plausible health outcomes from potential on-base exposures in the proposed mortality study (Kelly AFB Civilian Worker Mortality Study) to be conducted by the Kelly AFB Health Issues Working Group.

5. Data are not available for the evaluation of misting or the incineration of cyanide waste.

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Appendix A
Air Dispersion Modeling Methodology

Air Dispersion Modeling
This appendix presents ATSDR's rationale for the use of models to estimate the concentration of ambient air pollutants from past operations at Kelly Air Force Base.

Air Modeling
Air dispersion models are mathematical equations that *predict* (simulate or model) the movement of chemicals in the air. This movement is also called dispersion since the chemicals disperse after they are released into the air. The mathematical equations are entered into a computer program for ease of use. Data needed for these air dispersion models include weather data, the amount of pollutants released to the air over time, site topography, and site geometry. In studies comparing estimated concentrations from air dispersion modeling to air sampling measurements, the Industrial Source Complex (ISC) model used here, in areas similar to Kelly Air Force Base have been shown to be accurate within two-times to one-half the actual result [7]. For instance, if the "real" value is 1 $\mu g/m^3$, the model could show a range of 2 $\mu g/m^3$ to 0.5 $\mu g/m^3$. The largest uncertainty is the emission data which are not accounted for in this error range.

Where air monitoring shows a "real" result for a snapshot in time on one specific location, the model produces one result for each hour modeled at each specified location that must be adjusted for this error range. The modeled hourly results can be used to calculate 24-hour or annual averages or maximums.

Limitations of air models also include:

- Difficulties in obtaining representative meteorological data and emissions data.
- Large uncertainties at short time frames such as one hour or one day. Models are better at predicting long term averages such as one year.
- Complex meteorological and terrain conditions that are not accounted for in the meteorological data and the mathematical equations.
- Results that are approximations with some models validated in the field.

Four advantages of models:

- Models can be used to estimate a substance's concentration for different time periods for which both emissions and meteorological data exist. The ISCST3 model used in this report generates an hourly model. The hourly results can be compiled to generate maximum and average values. Maximum and average results can also be generated for any time period such as a day, month, or year.
- Models can be used to estimate the level of various substances existing in the ambient air as a result of emissions from a single source or multiple sources.
- Models can average short-term fluctuations in emissions and meteorological conditions, resulting in a long-term average.
- Models can estimate a substance's concentration at an unlimited number of locations.

Air Sampling
Air sampling using conventional equipment has the advantages of producing data that are

considered “real” results. “Real” in the sense that the mix of chemicals identified actually existed in the air at the location and time the sample was taken. Moreover, this mix of chemicals was the result of many different sources. Conventional equipment is defined here as fixed stationary samplers with samples collected by drawing air through a filter or tube and the filter and tube analyzed at a later time for the chemicals collected. Although the sample is considered “real,” there are several disadvantages in the sampling procedure:

- Sampling substances arising from many and varied sources hinders the correlation of an air sample to a single facility. Sources not pertinent to the investigation could influence the interpretation of the results. For instance, air samples collected near idling buses may have higher concentrations of chemicals found in diesel exhaust than is present in ambient air as a result of emissions from the source being investigated.

- Sampling results are based on conditions at the time of the sampling event. These conditions include the meteorological conditions and the amount and rates at which the chemicals were released. These conditions could be an extremely low or high condition and not representative of average conditions. Conversely, samples are usually collected over a period of time (several hours to 12 hours), consequently, the result would average out short term small and large transient chemical concentrations.

- Air sampling is expensive and takes a long time to obtain representative results.

Air Modeling Input Parameter Comparison

Peer reviewers of the Phase I PHA recommended ATSDR investigate the effect of different input values for the half life of hexavalent chromium [37]. This section describes the results of variables in that and other input parameters. Table A-1 provides a summary of these details.

ATSDR investigated various input parameters to determine their potential effects on the results of air dispersion modeling. The following issues related to air dispersion modeling were addressed using the U.S. EPA Industrial Source Short Term (version 3, ISCST3) gaussian dispersion model:

1. effect of using different half lives for hexavalent chromium. 1 to 2,160 minutes was used
2. building downwash (effect with and without)
3. landscape (effect of using rural or urban)
4. building height (20 or 32 feet)
5. combinations of parameters

Five years of meteorological data were used (January 1986 through December 1990) from the San Antonio International Airport for surface air and the Del Rio International Airport, Del Rio Texas for upper air data.

For the analysis of the different parameters, ATSDR assumed 12 chromium emission points. The details of these emission points are presented in Appendix B, Attachment 1.

Results are depicted in Figure A-1 and Figure A-2. While the true concentration is unknown (actual emission rates are not known), Figure A-1 indicates that as the half-life of hexavalent chromium increases, the estimated concentration at a downwind point near the base perimeter increases until the half-life value used is about 3 – 4 hours, at which point the estimated concentration is not changed by the longer half life. Use of a half-life above 3 – 4 hours does not increase the concentration at the model locations at the base perimeter. However, the distance from the base where the maximum concentration could be found would increase as the half-life is increased above 3 – 4 hours.

Figure A-1. **Hexavalent Chromium Half-lives**. Results indicate that chromium concentration at a point in the community near the fenceline north of the base* increases as the half-life approaches 3 – 4 hours (180–240 minutes). The concentration then becomes stable.

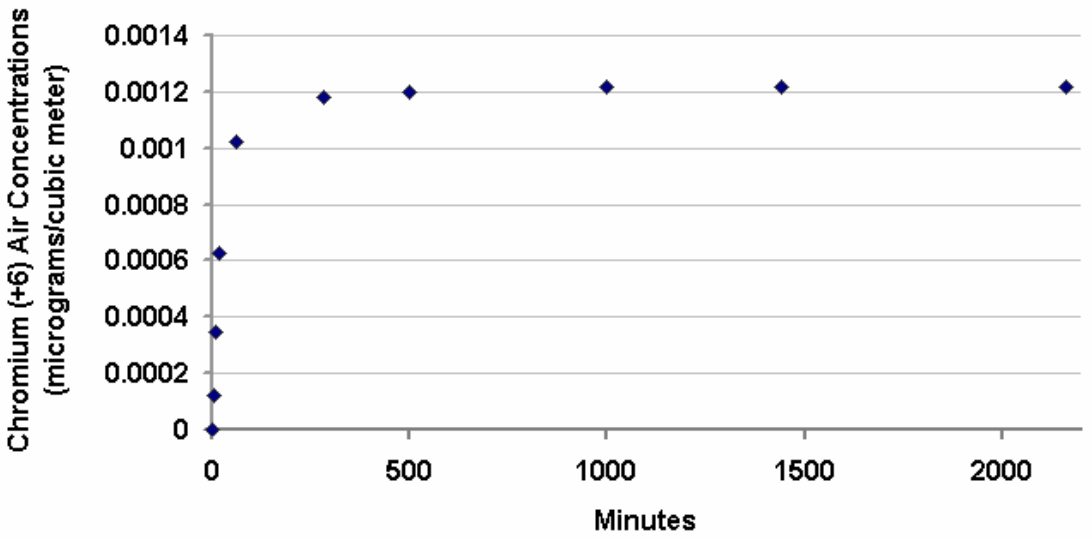


Figure A-2 indicates that the use of rural or urban landscape, with or without downwash, at a 20 or 32 foot release height will not result in a significant change in the estimated concentration of hexavalent chromium off base. On base concentrations are most significantly affected by release height, rural landscape, and without downwash, respectively, resulting in the highest breathing zone concentrations nearer the source. Because the meteorology used for other contaminants is the same as that used for hexavalent chromium, the relative concentration differences would also apply to all other contaminants. This suggests that, depending on the input parameters selected, the concentration of contaminants on base could vary by a factor of about 3 at a specific point within 300 meters of the source and a factor of about 50 depending on the receptors location inside the base boundaries. Figure A-2 also illustrates that selection of input parameters will <u>not</u> affect the off-base concentrations of contaminants from Kelly AFB.

*This point is located at 641,600 meters west and 4,173,700 meters north of the origin of the geographic statewide grid, Texas South Central Zone, North American Datum of 1983.

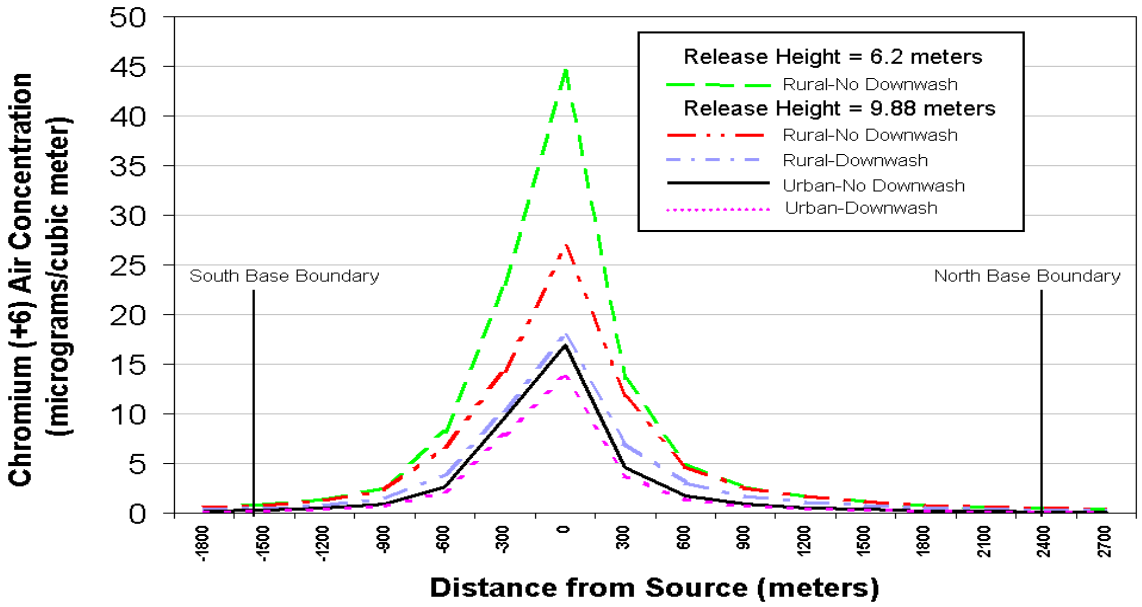


Figure A-2. **Input Parameter Comparison**. Selection of model parameters shown in the Figure have no effect on off-base concentrations of contaminants, but may have significant effects upon on-base concentrations.

Table A-1. Summary of parameters and assumptions common to aircraft and stationary source modeling.

Category	Data and Assumptions	
Dispersion Modeling	Used the U.S. EPA Industrial Source Complex Short Term Version 3 (ISCST3) model. Assumed that deposition or degradation in the atmosphere did not occur. The rural dispersion parameters were used. Downwash was not used except in the analysis of the parameters in Appendix A. The model assumptions inherent in the ISC model were used and include the Gaussian dispersion parameters derived from Pasquill-Gifford. These assumptions and other background data on this model can be found in two U.S. EPA manuals (Vol. I and Vol. II., 1995, http://www.epa.gov/scram001/tt22.htm#isc. See Appendix B for additional details.	
Meteorological data	Five years of meteorological data were used (January 1986 through December 1990) from the San Antonio International Airport for surface air and the Del Rio International Airport, Del Rio Texas for upper air data.	
Aircraft Modeling		
Dispersion Modeling	The ISC model input parameters were set so the emissions were contained in a series of volume sources. The size of the volume and its location behind the plane were set to specific values. The sensitivity of these values to the final results was not tested. The volume sources were assumed to disperse due to meteorological conditions. Aircraft operations may have created additional dispersion which could lead to lower downwind concentrations. See Appendix B for additional details.	
Number of Operations	336,000 total with 168,000 takeoffs and landings	The number of operations is a peak value in 1964 and is based on the relocation of a Kelly AFB employee.* Operations in previous years could be lower or higher. An operation assumed to be one takeoff and one landing and each operation consisting of taxi, startup or shutdown, runway rollway, and approach or takeoff.
Emissions	Based on engine tests of the B52H engine (TF33-3) and the F16	Other B52 engines included the Pratt and Whitney J-57. Previous engines or different models of the same engine type may have had more or less emissions. The tested engine compared to actually used engine emissions may be different due to wear or load conditions. Assumed that all emissions were gaseous. See Appendix B for details.
Time in mode	Based on a USAF reference. See Appendix B for details.	
Location	Based on existing runway and main long taxiway.	A second runway that no longer exists was not included.

Table A-1. Summary of parameters and assumptions common to aircraft and stationary source modeling.

Category	Data and Assumptions
Stationary Source Modeling	
Location and rate of releases	Data is Appendix B, Attachment 1 and based on three Air Force reports (March 27, 2000, June 2000, and December 2000). Emissions reported on an annual basis was averaged over a year.
Stack parameters	Based on March 27, 2000, June 2000, and December 2000 Air Force reports. Sources with no data were assumed to have a building height of 6.2 meters, exit gas temperature of 20ºC, exit gas velocity of 0.1 meters/second, and an inside diameter at the release point of 1 meter. These values are conservative in that they produce higher ambient air concentrations.

* Aircraft Noise in the Vicinity of Kelly Air Force Base, San Antonio, Texas (Updated Report), March 1994. HMMH Report No. 292610-B. Prepard fro U.S. Department of Justice by Harris, Miller, Miller & Hanson Inc., Lexington, Massachusetts.

Appendix B
Stationary and Aircraft Emissions

Appendix B

This appendix presents ATSDR's approach to estimating the concentration of ambient air pollutants from past operations at Kelly Air Force Base (AFB). The approach was completed in two steps: estimating emission rates and modeling the dispersion of the emissions. These steps are addressed individually for stationary source (industrial) emissions and aircraft emissions.

Air dispersion models are mathematical equations that *predict* (simulate or model) the movement of chemicals in the air. This movement is also called dispersion since the chemicals disperse (spread out) after they are released into the air. The mathematical equations are put into a computer program for ease of use. Data needed to estimate emissions rates include weather data, adjacent land use, building height and size, the amount of pollutants released to the air over time, and the release location of the pollutants. More specifically, the data needed include:

- Temperature of exit gas
- Diameter of stack at exit
- Exit gas velocity
- Location of the release in geographic coordinates
- Amount of pollutant being released over time (rate of release)
- Release height or stack height

Stationary Source Emissions

ATSDR obtained the location and the rate of releases from Kelly AFB (see Appendix B, Attachment 1). The information was provided in a report dated March 27, 2000, and updated in June and December, 2000. Where known, this information included building numbers and heights, heights of vents or stacks, descriptions of processes, specific chemicals, usage and emissions estimates, assumptions, and sources of the information.

ATSDR compared the past emission rates with previously modeled current emission rates to determine the need for additional modeling of those chemicals. ATSDR also considered whether stack heights, building locations, or other parameters were different and therefore, suggested whether additional modeling would be necessary. The following chemicals were addressed as stationary source emissions of potential concern with results presented in Table B-1: tetrachloroethylene (PCE), hexavalent chromium, methylene chloride, methyl ethyl ketone, benzene, ethyl benzene, formaldehyde, toluene, and xylene. Building numbers, locations, and emission values are listed in Attachment 1 for these chemicals. ATSDR was not able to obtain the temperature of the exit gas, diameter of stack at exit, exit gas velocity, or the release height for each of these release points. As a result, ATSDR assumed a set of stack values that would overestimate ambient air concentrations. These values are:

- Building Height: 6.200 meters (approximately 20 feet)
- Stack Gas Exit Temperature: 293 degrees Kelvin (20^{o}C or 68^{o}F)
- Stack Gas Exit Velocity: 0.10 meters/second (0.33 feet/second)
- Stack Inside Diameter at Release point: 1 meter (3.2 feet)

ATSDR assumed that all modeled chemicals were in the gas form and deposition (dry or wet) was not occurring. This assumption can overestimate the amount of chemical in the air. The likely form of most metals and hexavalent chromium in the air is as an aerosol or absorbed onto particulates. The amount of deposition of the aerosols and particulates would be a function of their size and mass distribution. These properties were not known so ATSDR assumed all the chemicals including chromium was in the gas form.

ATSDR also assumed that the nearby land use was rural and that the building height and size where the release occurred and nearby buildings did not influence the dispersion of the chemicals (this influence is called building downwash). In Appendix A, Air Modeling Input Parameter Comparison, ATSDR verified these inputs to be producing higher predicted concentrations than would occur if other inputs were used.

ATSDR modeled these emissions estimates using EPA's ISCST3 model.The ISCST3 model in flat terrain, as in the case of Kelly AFB, as an uncertainty from ½ to 2 times the predicted concentrations [7].

The predicted concentrations indicate that non-cancer health effects would be unlikely as no contaminant concentration exceeded noncancer comparison values (Table B-1). Two chemicals exceeded cancer comparison values and were further evaluated: tetrachloroethylene (PCE) and methylene chloride (Table B-1). Hexavalent chromium emissions were not included because the data provided were insufficient (see Hexavalent Chromium below for an explanation). Following are discussions of the emissions of these chemicals and health implications of the estimated levels.

Hexavalent chromium

The emissions from the plating operations were expected to be the largest potential contributor of hexavalent chromium emissions. ATSDR evaluated two time frames relating to hexavalent chromium emissions. Hexavalent chromium was emitted from five plating shops. The most significant were located in Buildings 258/295 and Building 301. Buildings 258/259 began operation in 1942 and shutdown in 1977. Building 301 replaced Building 258/259 in 1977 and included scrubbers to control emissions. The emission rates of hexavalent chromium from Building 258/259 are not known. The emission rates from Building 301 are based on stack tests completed in 1980. The time prior to the 1980 stack test is used to define past exposures because of the unknown emission rates from Building 301 prior to 1980 and unknown emission rates from Buildings 258/259.

ATSDR was interested in the time frames before and after the Building 301 stack test. Emissions before 1977 would potentially represent higher concentrations because it is not known if pollution control was in use in Building 258/259 while emissions from 1977 to 1980 are not certain. Emissions from 1980 would be more certain based on the stack test and be similar to current emissions. Emissions from 1980 would potentially represent lower concentrations than prior to 1977. Data located for chromium plating emissions were rare (3 data sources). Hexavalent chromium emissions were evaluated for 3 scenarios based on data sources and timeframes related to changes in emissions:

(1) air emissions estimated from *chromic acid usage* data before 1980,
(2) air emissions estimated from *energy usage* before 1980, and
(3) air emissions measured from *stack emissions* data and applied to 1980 and after.

Table B-1. Estimated maximum past ambient air concentrations from stationary source emissions.

Chemical	Estimated emission (TPY) [a]	Estimated Concentration [b] ($\mu g/m^3$) [c]	Chronic Non-Cancer Comparison Value ($\mu g/m^3$)	Worker Exposure Levels ($\mu g/m^3$)*	Cancer Comparison Value ($\mu g/m^3$)	Estimated Cancer Risk
hexavalent chromium	NA	-	-	-	-	-
methylene chloride	2940	123	1060 [e]	87,000	3 [f]	5E-05
PCE	1490	142	271 [e]	678,000	3 [g]	7E-05
benzene	0.04	0.00046	13 [e] intermediate	320	0.1 [f]	5E-09
formaldehyde	0.13	0.00075	10 [e]	922	0.08 [f]	1E-08
methyl ethyl ketone	305.	13	1000 [e]	1500	-	NA
toluene	0.0116	0.00013	300 [e]	375,000	-	NA
xylene	0.00517	0.00006	434 [e]	435,000	-	NA
ethyl benzene	0.0175	0.0002	1000 [h]	435,000	-	NA

a TPY or tons per year
b The estimated concentration was determined as the maximum off-base concentration.
c $\mu g/m^3$ or micrograms per cubic meter
d intermediate exposure value of <1year used as there is no chronic value.
e ATSDR minimum risk level (MRL)
f ATSDR cancer risk evaluation guideline (CREG)
g EPA Risk Based Concentration, Region 6.
h EPA RfC or EPA Reference Concentration
NA Not Applicable or Not Available
* NIOSH values were used for all except PCE and formaldehyde, where OSHA values were used. Values represent up to 10-hour daily exposures for up to 40 hours/week. OSHA values represent an 8 hour day, 5 days/week.

Kelly AFB provided two data sources for estimating hexavalent chromium air emissions prior to 1980 (scrubbers were installed in 1980 for pollution control). The data sources were

> (1) *usage of chromium trioxide* (used to make chromic acid) from one year of operation during the 1980s (the specific year was not reported), and
>
> (2) *emission estimates from energy usage* during one test of stack emissions on one scrubber (pre-scrubber concentrations were estimated from Tinker AFB energy use data formulation).

Kelly AFB provided a third source of information from *measured stack emissions* from one test of one scrubber in 1980 in Building 301. The quality of these data obtained from analysis of scrubber stack emissions is much higher than for either the chromic acid usage data or the energy usage data. Data from chromic acid usage and energy usage contain data gaps and little corroborating information, which ATSDR deems essential to reduce uncertainty in the results. Although the quantity of stack emissions data is low, ATSDR acknowledges these data are probably indicative of emissions after scrubbers were tested in 1980 in Building 301. Corroborating evidence from current emissions data supports this judgment. Sufficient quantitative data have not been provided for a quantitative assessment of emissions after the scrubber were installed in 1980. While a quantitative assessment is not possible, a qualitative evaluation does not indicate that evidence exists indicating levels of public health concern were likely to have been present after the scrubbers were tested (1980). ATSDR acknowledges that any evaluation would contain much uncertainty and insufficient to make a public health call.

Some of the information ATSDR requested from Kelly AFB could not be located. This information includes the number of air emissions scrubbers, when the operation began, size of chromic acid baths, chromic acid strength, and electricity used in plating operations at Kelly AFB. Because of these unknowns, it is not possible for ATSDR to estimate concentrations from potential past air emissions of hexavalent chromium with an appropriate degree of confidence to draw conclusions related to past exposures. Therefore, ATSDR concludes that the health hazard to the community before scrubbers were installed is *indeterminate*.

Methylene chloride

Non-cancer health effects from exposures to methylene chloride would not be expected because the maximum off-base concentration of methylene chloride did not exceed non-cancer comparison values (see Table B-1). The maximum off-base concentration of methylene chloride exceeded a cancer comparison value. Therefore, methylene chloride was further evaluated to determine the estimated risk for developing cancer from the maximum exposure. Methylene chloride is considered a probable human carcinogen based on inadequate human data and sufficient animal data. The estimated risk for a continuous lifetime exposure at the maximum concentration is considered a *low increase* in risk. Animal studies served as the basis for calculating risk as no human cancers have been reported in the scientific literature at these estimated levels. Using the maximum value estimated air concentrations based on the modeling, risks are likely to be overestimated. Using the maximum estimated concentration in the community, potential exposures levels are about 3500 times less than levels potentially associated with reported cancer effects in humans [38]. Although there is some risk from exposure to

methylene chloride, ATSDR would not expect that an increase in cancer would be observed in the community from exposures to these estimated levels of methylene chloride.

PCE
The maximum off-base concentration of PCE did not exceed non-cancer comparison values (see Table B-1). While PCE has been confirmed as an animal carcinogen, the carcinogenicity of PCE in humans continues to be investigated. The maximum off-base concentration of PCE exceeded a cancer comparison value based on animal studies and was further evaluated. The estimated risk for developing cancer in the community from a continuous lifetime maximum exposure to the maximum concentration of PCE is considered a *low increase* in risk. PCE exposure at these levels has not been associated with cancer in humans. ATSDR would not expect adverse health effects would be observed as a result of exposures at these levels under these exposure conditions [39].

Aircraft Emissions

ATSDR estimated the concentrations of organic chemicals in the ambient air from aircraft emissions using air modeling. Data on metal emissions were not available. This section discusses the inputs used in the model and the modeling process. ATSDR reviewed data from the Air Force and Navy on airplane emissions to select model input parameters. The input parameters were selected to be conservative (i.e., worst emissions) in most cases. As a result, ATSDR modeled the maximum reported annual operations of 336,000 in 1964 and assumed all operations were conducted by the B52H aircraft which emits the most pollution overall from data ATSDR reviewed. ATSDR also modeled emissions from a F16 aircraft to provide perspective. A B52 has eight engines and an F16 has one engine. Emissions information is available on 69 organic chemicals and ATSDR modeled the emissions of six chemicals based on amounts emitted and toxicity. These chemicals included acetaldehyde, acrolein, benzene, butadiene, formaldehyde, and naphthalene. The concentrations of these six chemicals in the environment were estimated at 5,100 point locations (the points were 300 meters apart) in and around Kelly AFB. Specific details of the modeling are presented in the remainder of this section.

Model Inputs

The Industrial Source Complex-Short Term (ISCST) model was used to perform the air modeling. To use this model, information on the source of pollutants, ambient meteorology, and information on receptor locations must be entered into the model. The model simulates the movement of the pollutants in the atmosphere and calculates a concentration at the given receptor locations. *The emissions were treated as a series of volume sources behind the aircraft (see page 32 for details).*

Source of Pollutants
The source of the aircraft emissions was aircraft operations at Kelly AFB. To use the model, ATSDR must know the amount of each type of pollutant released per unit of time and the location of the release. Since the aircraft move throughout the base, the release of the pollutants would occur at many different locations.

Obtaining information about the source and location of pollutants from the aircraft was a four step process:

1. Determining the types of aircraft at Kelly AFB
2. Obtaining the number of flight operations performed by each aircraft (takeoffs, landings, others)
3. Obtaining the amount and types of pollutants released from each aircraft.
4. Identifying the movement of the aircraft (location and time spent at the location).

Types of aircraft at Kelly AFB.

Kelly AFB was established as a military air field in 1917 and many different types of aircraft have flown through Kelly AFB. ATSDR obtained the following list of aircraft from Kelly AFB [40, 41]:

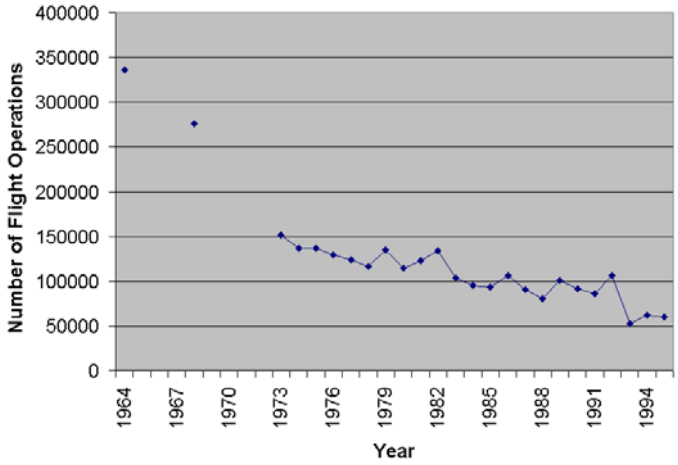
A-10	B-58	C-141	C-97	F16	KC-135	T-34
A-4	B-727	C-17	DC-9	F-18	P-38	T-37
A-6	B-757	C-2	F-100	F-4	P-47	T-38
B-1	C-118	C-21	F-101	F-80	P-51	T-39
B-17	C-119	C-47	F-102	F-84	SR-71	T-41
B-24	C-12	C-5	F-104	F-86	SW-4	T-43
B-29	C-121	C-54	F-105	F-89	SWB	T-45
B-36	C-123	C-7	F-106	F-94	T-1	T-6
B-50	C-124	C-74	F-14	FB-111	T-28	UH-1
B52	C-130	C-9	F-15	KC-10	T-33	XC-99

ATSDR limited the aircraft emissions modeling to the B52H because it was the largest emitter of pollutants in the limited available data. This simplification is a conservative assumption in that ATSDR modeled a worst-case (most emissions) scenario. This simplification is explained in additional detail in the following sections. Because the operations per type of plane used in 1964 was not known to ATSDR at the time this report was prepared, ATSDR also modeled emissions from the F16 to simulate a scenario with lower emissions. The F16 did not exist in 1964 but is used as a surrogate for a low emission military aircraft.

Number of flight operations performed by each aircraft

Ideally, the number and types of operations for each aircraft is used. ATSDR only found historical information on the total number of operations per year as depicted in Figure B-1. An aircraft operation is one take off or one landing. A touch and go (landing and immediate take off) is two operations [14].

Figure B-1. Annual Operations



To present a worst-case (most emissions) scenario, ATSDR modeled the 1964 operations of 336,000 operations per year. Since information on all of the types of aircraft was not available, ATSDR assumed all 336,000 operations were performed by the B52H or the F16.

Amount and types of pollutants released from each aircraft
ATSDR found emissions data on the following aircraft:

A-10A	F-106 (A,B)	T33A
B-52 (D, F) B-52H	F15 (A,B,C,D)	T-37B
C-130 (A, D, E, H)	F-16 (A,B)	T-38 (A,B)
C-141 (A,B)	F4 (C, D, E, F)	T-39 (A,B)
C-21A	FB-111A	T-41 (A,B,C)
C-5 (A,B)	KC-10A	T-43A
C-9A	KC-135 (A,D)	

Available emission data included carbon monoxide, carbon dioxide, total hydrocarbons, nitrogen oxides, particulate matter, and specific organic chemicals. Carbon monoxide, carbon dioxide, nitrogen oxides, and particulate matter were not modeled because these compounds are typical in urban air while total hydrocarbons is not sufficiently specific for a toxicological evaluation. ATSDR focused its modeling on specific organic chemicals which are listed below.

ATSDR obtained and used emissions from these aircraft using JP-4 fuel versus the currently used JP-8 fuel. Kelly AFB completed the conversion from JP-4 jet fuel to JP-8 jet fuel in 1994[13]. JP-4 has been used by the Department of Defense since 1951 [42].

As stated previously, ATSDR simplified the modeling to the emissions of the B52H because it presented a worst-case (most emissions) scenario. ATSDR identified the B52H as the worst case as follows. The F16 was used to simulate planes with lower emissions.

ATSDR reviewed the available emissions data by total hydrocarbons for different aircraft using JP-4. ATSDR identified the plane and engines that emitted the most hydrocarbons. Table B-2 lists these aircraft and engines by flight operation mode because the aircraft and their engines emit different amounts of chemicals during each mode.

Table B-2. **Summary of aircraft and engines with the most hydrocarbon emissions per aircraft mode [43].**

Mode	Plane	Engines	Hydrocarbon Emissions Per Plane Per Event (Metric Tons)*
Startup	B52H	TF33-3	0.0582
Taxi Out	B52H	TF33-3	0.113
Engine Check	B52H	TF33-3	0.0582
Runway Roll	B52H	TF33-3	0.000176
Climb 1	B52H	TF33-3	0.000193
Climb 2	B52H	TF33-3	0.000213
Approach 1	KC-135	J57-59W	0.00251

Mode	Plane	Engines	Hydrocarbon Emissions Per Plane Per Event (Metric Tons)*
Approach 2	C5	TF39-1	0.000783
Landing	B52H	TF33-3	0.00699
Taxi In	B52D	J-57-19W/J-57-43WB	0.0418
Shutdown	B52D	J-57-19W/J-57-43WB	0.0106
Touch&Go	KC-135	J57-59W	0.0033

* The hydrocarbon emissions per plane per event from this reference are most likely not correct. ATSDR checked these values against possible derivation. These hydrocarbon emissions per plane per event are based on time-in-mode, engine setting, and HC emission rate. The power setting for taxi-out is idle which has the highest HC emissions rate. For the TF33-3 engine at idle, the rate is 84 g/kg fuel. The fuel use rate is 0.11 kg/s so the HC emission rate is 9.24 g/s. For 113 kilograms HC emitted during taxi out (Table B-2), the time-in-mode would need to be 3.4 hours which seems very unrealistic. ATSDR checked the KC-135A from this reference for taxi-out and came up with 11.5 hours which is even more unrealistic. ATSDR suspects a systematic error in Table A of Seitchek [43]. It's possible that the units for Table A are kilograms and not metric tons. Because the values in Table B-2 were only used for a comparison among planes and not used in the emissions modeling, the error in Seitchek (1985) does not change our results. The hydrocarbon rates used in the modeling was 94 g/kg fuel 0.14 kg/s of fuel (Spicer et al 1988) [16]. These values are similar to Seitchek (1985). The times-in-mode used in the ATSDR modeling was 9 minutes for taxi-out (Naugle et al 1975) for a total of 7.1 kg HC released during taxi-out [44].

These data indicate that the B52H aircraft emitted the most hydrocarbons overall [43]. The C-5 had the highest emission rates during Approach 2 while the B52D had the highest emission rates during Taxi In and Shutdown and the KC-135 had the highest emission rates during Approach 1 and Touch and Go.

The hydrocarbon emissions for each mode of the B52H with the TF33-P3 engine (Table B-3) was compared to Table B-2. From these tables, the B52H is not the worst emitter in four of the 12 modes, with the most significant difference is in Approach 2. Because the B52H was the worst emitter for 8 of the 12 modes, ATSDR decided to use the B52H as the worst-case aircraft to model.

Table B-3. Hydrocarbon emissions per event for the B52H aircraft with TF33-P3 engines.

Mode	Hydrocarbon Emissions Per Plane Per Event (Metric Tons)*
Startup	0.0582
Taxi Out	0.113
Engine Check	0.0582
Runway Roll	0.000176
Climb 1	0.000193
Climb 2	0.000213
Approach 1	0.00178
Approach 2	0.000595
Landing	0.00699
Taxi In	0.0413
Shutdown	0.0105
Touch&Go	0.0029

*USAF Aircraft Engine Emissions Estimator, Glenn D. Seitchek, ESL-TR-85-14, November 1985.

Additional parameters required for modeling the B52H/TF33-P3 are time in mode, fuel flow, and hydrocarbon emissions per fuel rate shown in Table B-4.

Table B-4. Operating parameters for a TF33-P3 engine in different B52H aircraft modes.

Aircraft Mode	Engine Thrust	Minutes*	Fuel Flow Per Engine (1000 lb / hr)**	HC Emissions Per Engine (lb/1000 lb fuel)**
Startup	Idle	20	1.052	94.00
Outbound Taxi	Idle	9	1.052	94.00
Engine Check	Military	4.5	7.105	0.03
Runway roll	Military	0.7	7.105	0.03
Climbout I	Military	0.7	7.105	0.03
Climbout II	Military	0.8	7.105	0.03
Approach I	Idle	3	1.052	94.00
Approach II	Idle	1	1.052	94.00
Landing on runway	Idle	1	1.052	94.00
Inbound Taxi	Idle	12	1.052	94.00
Idle at shutdown	Idle	4.8	1.052	94.00

*USAF Aircraft Pollution Emission Factors and Landing and Takeoff (LTO), Dennis Naugle, et al, AD/A-006 239 (February 1975)

**Aircraft Emissions Characterization," C.W. Spicer, M.W. Holdren, S.E. Miller, D.L. Smith, R.N. Smith, D.P. Hughes. Final Report, March 1988, Engineering and Services Laboratory, Air Force Engineering & Services Center, Tyndall Air Force Base, ESL-TR-87-63.

The constituents of the total hydrocarbons (HC) from a TF33-P3 engine have been reported by

the Air Force and shown in Table B-5. The Air Force reports the emission test results in $\mu g/m^3$ for polyaromatic hydrocarbons and parts per million Carbon (ppmC) for all other pollutants. $\mu g/m^3$ and ppmC are converted to percent weight of hazardous air pollutant (HAP) emitted in the hydrocarbon emissions using the following formula:

% wt HAP/HC = ([HAP] / [HC]) x (Number of C in HC / Number of C in HAP) x (MW_{HAP} / MW_{HC})

where:
[HAP] = concentration of organic compound in ppm_vC
[HC] = concentration of total hydrocarbons in ppm_vC
Number of C = Number of carbon molecules = 9.3*
MW_{HAP} = Molecular Weight of the HAP]
MW_{HC} = Molecular weight of the total hydrocarbons = 130*

*Douglas, Everett, Naval Aviation Depot, Naval Air Station, San Diego, California. Email record of personal communication regarding information about converting units and data on the number of carbons and molecular weights of total hydrocarbons in jet fuel, February 12, 2001. A derivation of this formula is presented in Response to Comments.

From this data, the amount of HAPs emitted per unit time (e.g., grams/second) is calculated, in general, as follows:

Amount of fuel burned per time in each mode *
Amount of HC emitted per fuel burned *
Number of engines *
% wt HAP/HC *
Time in mode *
Number of operations per hour =
Amount of HAPs emitted per unit time (grams/second)

* multiplication

Table B-5. Chemicals in exhaust from the TF33-P3 engine using JP-4 jet fuel.

	Power Setting							
	Idle		30%		75%		100%(military)	
	ppm C	%wt HAP/HC	ppm C	%wt HAP/HC	ppm C	%wt HAP/HC	ppm C	%wt HAP/HC
Methane	37.57	0.03425	2.425	0.03578	0.704	0.13454	0.439	0.15851
Ethane	5.098	0.00435	0.334	0.00462	0.01	0.00179	0.004	0.00135
Ethylene	47.405	0.03777	15.171	0.19568	1.368	0.22854	0.164	0.05176
Propane	0.893	0.00075	0.026	0.00035	0.005	0.00088	<0.001	--
Acetylene	28.368	0.02098	3.925	0.04698	0.374	0.05798	0.068	0.01992
Propene	43.344	0.03454	5.048	0.06511	0.289	0.04828	0.041	0.01294
1-Butene	18.489	0.01473	1.814	0.02339	0.107	0.01787	0.049	0.01546
1,3-Butadiene	11.981	0.00920	0.571	0.00710	0.024	0.00387	<0.001	--
1-Pentene	5.818	0.00464	0.595	0.00767	0.065	0.01086	0.042	0.01326
C5-ene	2.563	0.00204	0.225	0.00290	0.017	0.00284	<0.001	--
n-Pentane	4.464	0.00366	0.112	0.00149	<0.001	--	<0.001	--
C5-ene	1.584	0.00126	0.013	0.00017	<0.001	--	<0.001	--
C5-ene	0.835	0.00067	0.052	0.00067	<0.001	--	<0.001	--
2-Methylpentane	11.059	0.00902	0.192	0.00254	0.005	0.00086	<0.001	--
3-Methylepentane	8.438	0.00689	0.335	0.00442	0.006	0.00103	<0.001	--
1-Hexene	5.587	0.00445	0.521	0.00672	0.023	0.00384	<0.001	--
n-Hexane	14.688	0.01198	0.339	0.00448	0.005	0.00086	<0.001	--
Methylcyclopentane + unk	7.834	0.00000	0.246	0.00000	0.059	0.00000	0.077	0.00000
Benzene	12.499	0.00924	1.698	0.02032	0.16	0.02481	0.029	0.00849
2-Methylhexane	25.488	0.02073	0.571	0.00752	0.012	0.00205	0.004	0.00129
3-Methylhexane	20.534	0.01670	0.589	0.00775	0.009	0.00153	0.006	0.00193

	Power Setting							
	Idle		30%		75%		100%(military)	
	ppm C	%wt HAP/HC	ppm C	%wt HAP/HC	ppm C	%wt HAP/HC	ppm C	%wt HAP/HC
n-Heptane	26.87	0.02185	0.606	0.00798	0.016	0.00273	0.011	0.00354
Methylcyclohexane	31.824	0.02536	0.643	0.00829	0.014	0.00234	0.007	0.00221
Toluene	23.27	0.01740	1.446	0.01750	0.076	0.01191	0.022	0.00652
2-Methylheptane	21.226	0.01721	0.339	0.00445	0.013	0.00221	0.009	0.00289
3-Methylheptane	31.651	0.02566	0.687	0.00902	0.018	0.00306	0.01	0.00321
n-Octane	28.915	0.02345	0.595	0.00781	0.014	0.00238	0.009	0.00289
Ethylebenzene	5.558	0.00419	0.32	0.00390	0.017	0.00269	0.008	0.00239
m+p-Xylene	30.787	0.02320	1.332	0.01625	0.048	0.00758	0.024	0.00716
Styrene	11.174	0.00826	0.38	0.00455	0.016	0.00248	0.012	0.00351
o--Xylene	9.734	0.00734	0.413	0.00504	0.016	0.00253	0.008	0.00239
n-Nonane	22.406	0.01814	0.464	0.00608	0.012	0.00204	0.01	0.00321
p-Ethyltoluene	8.352	0.00634	0.346	0.00425	0.009	0.00143	0.016	0.00481
1,2,4-Trimethylbenzene	15.581	0.01182	0.566	0.00695	0.016	0.00254	0.018	0.00541
n-Decane	21.715	0.01755	0.498	0.00652	0.019	0.00322	0.014	0.00448
Methlybenzaldehyde+C10H14	8.179	0.00624	0.497	0.00613	0.059	0.00943	0.062	0.01872
Undecane	26.179	0.02113	0.606	0.00792	0.027	0.00457	0.042	0.01343
Naphthalene	10.138	0.00738	0.395	0.00465	0.035	0.00534	0.05	0.01442
Dodecane	29.261	0.02360	0.522	0.00681	0.023	0.00389	0.066	0.02108
Tridecane	21.398	0.01724	0.452	0.00589	0.034	0.00574	0.08	0.02553
Tetradecane	5.011	0.00403	0.405	0.00528	0.041	0.00692	0.184	0.05867
Formaldehyde	15.54	0.02650	4.009	0.11068	0.423	0.15126	0.083	0.05607
Acetaldehyde	1.802	0.00226	1.564	0.03168	0.211	0.05535	0.036	0.01784
Acrolein	1.833	0.00195	0.501	0.00861	0.051	0.01135	<0.001	--
Propananldehyde	0.461	0.00051	0.268	0.00477	0.019	0.00438	0.005	0.00218
Acetone	<0.001	--	0.432	0.00769	0.067	0.01545	0.025	0.01089
Benzaldehyde + unk	3.9303	0.00338	1.668	0.02325	0.2	0.03611	<0.001	--
Glyoxal	1.68	0.00277	1.368	0.03650	0.126	0.04354	0.024	0.01567
Methylglyoxal	5.31	0.00725	0.817	0.01804	0.077	0.02203	0.032	0.01729
Biacethyl	0.542	0.00066	0.257	0.00509	0.024	0.00615	0.013	0.00630

Polyaromatic Hydrocarbons

		Idle		30%		75%		100%
	$\mu g/m^3$	%wt HAP/HC	$\mu g/m^3$	%wt HAP/HC	$\mu g/m^3$	%wt HAP/HC	$\mu g/m^3$	%wt HAP/HC
Naphthalene	320	0.00041	45	0.00093	9	0.00240	2.3	0.00116
1-methyl naphthalene	430	0.00055	33	0.00068	3.6	0.00096	1	0.00050
2-methyl naphthalene	350	0.00045	49	0.00101	4.5	0.00120	1.1	0.00055
Dimethyl naphthalene	53	0.00007	8.8	0.00018	0.043	0.00001	0.064	0.00003
Dimethyl naphthalene isomer	320	0.00041	33	0.00068	1.8	0.00048	0.53	0.00027
1,2-dimethyl naphthalene	530	0.00067	53	0.00109	3.2	0.00085	1.2	0.00060
1,4- & 2,3 dimethyl naphthalene	140	0.00018	14	0.00029	0.8	0.00021	0.29	0.00015
2,6-dimethyl naphthalene	32	0.00004	3.3	0.00007	0.19	0.00005	0.088	0.00004
Dimethyl naphthalene isomer	21	0.00003	11	0.00023	1.5	0.00040	0.1	0.00005
Dimethyl naphthalene isomer	40	0.00005	1.9	0.00004	0.72	0.00019	0.22	0.00011
Phenanthrene	4.8	0.00001	0.22	0.00000	0.045	0.00001	0.019	0.00001

	Power Setting							
	Idle		30%		75%		100%(military)	
	ppm C	%wt HAP/HC	ppm C	%wt HAP/HC	ppm C	%wt HAP/HC	ppm C	%wt HAP/HC
Anthracene	9.7	0.00001	0.76	0.00002	0.32	0.00009	0.11	0.00006
Fluoranthene	8.9	0.00001	0.64	0.00001	0.27	0.00007	0.095	0.00005
Pyrene	0.2	0.00000	0.012	0.00000	0.012	0.00000	0.01	0.00001
Benz[a]anthracene	0.2	0.00000	0.034	0.00000	0.026	0.00001	0.021	0.00001
Chrysene	<0.01	--	<0.01	--	<0.01	--	<0.01	--
Benzo[e]pyrene	<0.01	--	<0.01	--	<0.01	--	<0.01	--
Benzo[a]pyrene	<0.01	--	<0.01	--	<0.01	--	<0.01	--
Perylene	<0.01	--	<0.01	--	<0.01	--	<0.01	–

*C.W. Spicer, M.W. Holdren, S.E. Miller, D.L. Smith, R.N. Smith, D.P. Hughes. "Aircraft Emissions Characterization," Final Report, March 1988, Engineering and Services Laboratory, Air Force Engineering & Services Center, Tyndall Air Force Base, ESL-TR-87-63.

From Table B-5, ATSDR selected the following 6 chemicals (Table B-6) to model based on emission rates and toxicity.

Table B-6. **Selected chemicals in TF33-P3 exhaust for air dispersion modeling.**

One TF33-P3 Engine with JP-4 Fuel

	Power Setting							
	Idle		30%		75%		100%	
	ppm C	%weight(wt) HAP/HC	ppm C	%wt HAP/HC	ppm C	%wt HAP/HC	ppm C	%wt HAP/HC**
1,3-Butadiene	11.981	0.00920	0.571	0.00710	0.024	0.00387	<0.001	0.00030
Benzene	12.499	0.00924	1.698	0.02032	0.16	0.02481	0.029	0.00849
Naphthalene	10.138	0.00738	0.395	0.00465	0.035	0.00534	0.05	0.01442
Formaldehyde	15.54	0.02650	4.009	0.11068	0.423	0.15126	0.083	0.05607
Acetaldehyde	1.802	0.00226	1.564	0.03168	0.211	0.05535	0.036	0.01784
Acrolein	1.833	0.00195	0.501	0.00861	0.051	0.01135	<0.001	0.00042

**Non-detects were converted to %weight based on the detection level of 0.001 % weight.

ATSDR performed a screening air dispersion model by selecting a single discharge point on the runway for all emissions. Results of this screening model indicated the need for a more detailed modeling effort. To account for emissions during the movement of aircraft around the base during operations, a more detailed modeling effort was initiated using the following assumptions about where the aircraft were modeled (aircraft mode) and how long they stayed at each location, how long they spent in each engine thrust mode, and the engine settings and corresponding emissions at each location and during each engine thrust mode.

Identifying the Movement of Aircraft.

The location of the jet engines as they operated is important for determining the dispersion of the emissions. These locations would have included the runways, taxiways, parking areas, maintenance areas, approach and takeoff routes, and other areas. The changes of these locations would also be important as well as the routes each type of plane may have used. One important change was the use of two runways. Runways 15/33 and 14/32 were operated together from 1951 through the mid 1960s. These two runways were operated simultaneously. Runway 14/32 was closed in the mid 1960s [45].

Because of the very limited information about aircraft movement, ATSDR simplified the emission locations to Runway 15/33 and the single 10,000 foot taxiway parallel to and just east of Runway 15/33. ATSDR calculated emissions after takeoff and on approach for up to 6 miles. The

aircraft mode and the modeled locations are shown in Table B-7.

Forty-eight volume sources were used to represent taxiway emissions. Fourteen were used to represent takeoffs. Thirty were used to represent climbout. Eighty were used to represent approach. These sources represent aircraft movement at approximately 3-second intervals. Volume sources in each mode (taxi, takeoff etc) were spaced along a line according to their respective speed during that mode.

Table B-7. Aircraft mode and modeled locations.

Aircraft Mode	Engine Thrust*	Minutes**	Modeled Location
Startup	Idle	20	Taxiway
Outbound Taxi	Idle	9	Taxiway
Engine Check	Military for B52 Military and afterburn for F16	4.5	End of runway where takeoff roll began
Runway roll	Afterburn for F16 and Military for B52	0.7	Runway
Climbout I	Afterburn for F16 and Military for B52	0.7	Straight trajectory from runway
Climbout II	Military	0.8	
Approach I	Idle	3	Straight trajectory into runway
Approach II	Idle	1	
Landing on runway	Idle	1	Runway
Inbound Taxi	Idle	12	Taxiway
Idle at shutdown	Idle	4.8	Taxiway

* USAF Aircraft Engine Emissions Estimator, Glen D. Seitchek, Air Force Engineering and Services Center, HQ AFESC/RDVS, Tyndall AFB, Florida, November 1985.

**USAF Aircraft Pollution Emission Factors and Landing and Takeoff (LTO) Cycles, Dennis F. Naugle and Steven R. Nelson, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, February 1975.

The direction the aircraft take off and land is dependent on the wind direction. Aircraft take off and land into the wind. For this analysis, bi-directional takeoffs and landings were incorporated. Using climatological data for San Antonio which show the prevailing wind direction to be from the southeast during the summer months (March through September), it was assumed that takeoffs and landings occur from north/northwest to south/southeast during this period [46]. During winter months (October through February), takeoff direction and landings were reversed (south/southeast to north/northwest) since the prevailing wind direction reverses to flows from the

north and northeast.

Meteorology
Meteorological data for the ISCST3 model were obtained through U.S. EPA from the San Antonio International Airport for surface data and the Del Rio International Airport, Del Rio Texas for upper air data.

Modeling Process

- All emissions were modeled as volume sources in the ISCST3 dispersion model.

- The volume sources were shifted 30 meters behind the assumed aircraft location to account for jet blast displacement.

- Emissions from all four aircraft modes (taxi, takeoff, climbout, and approach) were included in dispersion modeling.

- The concentrations of the six organic chemicals were estimated at 5,100 points in and around Kelly AFB. The points were distributed 300 meters apart.

- Emissions were calculated based on 336,000 annual operations. Hourly emissions (in g/s) were calculated from an hourly operations value of 19.2 landings and takeoffs per hour. Touch-and-go operations were modeled as a landing and takeoff because the number of touch-and-go operations were not included as a specific number. This means that the 336,000 annual operations were divided into 168,000 takeoffs and 168,000 landings.

- Takeoff and Climbout power settings (and associated fuel flow and hydrocarbon emissions) were set to 100%. Approach and taxi power settings were set to "idle" as described in the previous section. Modeled taxiways were limited to the single 10,000 taxiway parallel to and just east of Runway 15-33.

- Initial horizontal dispersion parameters were assumed 20 meters (estimated at one-third of the B52H wingspan).

- Initial vertical dispersion parameters were assumed 30 meters, based on a review of Photographic Measurements of USAF Aircraft Plume Rise (Music P D, Hunt J S, Naugle DF. Civil and Environmental Engineering Development Office Tyndall AFB FL Detachment 1 [ADTC)] Report Number CEEDO-TR-77-57).

- A release height of 2 meters was assumed for taxiway and takeoff sources.

- After the initial displacement from the engine (30 meters up and down and 20 meters side to side) the plume was considered to be at ambient temperature.

- Source release heights for climbout sources varied from approximately 45 to 1375 meters.

- Source locations along the climbout track were calculated along a projected path computed from a 110 knot climbout speed (assumed), a 3000 fpm climbout rate (assumed), and the 1.5 minute time-in-mode (from EDMS)[47].

- Source release heights for approach sources varied from about 480 meters to 0 meters above ground. Source locations along the approach track were calculated along a projected path computed from the 4 minute time-in-mode (from EDMS), a 75 knot approach speed (assumed), and a 3 degree glide slope [48].

- Source locations for runway role were based on accelerating motion. A beginning speed of approximately zero knots and an ending speed of approximately 110 knots was used to calculate source locations along the runway at 3-second intervals. A 42 second time-in-mode (from EDMS) was used.

- A 46-minute taxi time was used based on data presented in a previous section. The taxi time is the total time for taxi during takeoff and taxi during landing (see Table B-4)and includes time for startup (20 minutes), outbound taxi (9 minutes), inbound taxi (12 minutes), and idle at shutdown (4.8 minutes). This data was obtained from USAF Aircraft Pollution Emission Factors and Landing and Takeoff (LTO), Dennis Naugle, et al, AD/A-006 239 (February 1975).

- A constant speed of 2.5 knots was assumed for aircraft movement along the taxiway.

- Forty-eight volume sources were used to represent taxiway emissions. Fourteen were used to represent takeoffs. Thirty were used to represent climbout. Eighty were used to represent approach. These sources represent aircraft movement at approximately 3-second intervals. Sources in each category were spaced according to their respective speed during that mode.

Sensitivity Analysis

ATSDR modeled air emissions from a worst-case aircraft (B52) and a best case aircraft (F16) to describe the possible range of air emissions regardless of the specific types of planes that actually were responsible for air emissions. Modeling a fleet of known aircraft would result in emissions that are expected to be within the range estimated by modeling the worst and best cases. Using the revised scenario described herein at Kelly AFB, the range of possible values changed from a factor of 2 to a factor of about 5, with the worst-case values remaining the same.

ATSDR reran the modeling of the F16 emissions with a change in the emission rate during engine check. The engine check emission rate used and evaluated in the Past Air Emissions Health Consultation for Kelly Air Force Base was set at afterburner mode (also called stage 1 augmentation). The emission rate was changed to military power (also called 100% power) in the analysis herein. Engine check emission for the afterburner setting consisted of 3.7 g/s for

benzene and butadiene. Engine check emissions for military power consisted of 1.1 g/s for benzene and 0.92 g/s for butadiene. From the modeling, Figure B-4a and Figure B-5a were redrawn as Figure B-4b and Figure B-5b. The change in this emission rate reduced the predicted concentrations by a factor of 2 for the F16. Table B-8 shows the results for the F16. With the revision, the difference in risk between the F16 and the B52 is about 4 times for butadiene and 5-6 times for benzene.

The U.S. Army Center for Health Promotion and Preventive Medicine Environmental Health Risk Assessment Program (CHPPM), in response to our report, modeled past aircraft emissions using the Federal Aviation Administration's EDMS model[49]. ATSDR has recently been given a draft document. The report includes modeled ambient air concentrations from aircraft emissions but does not include calculations of cancer risk. CHPPM's predicted air concentrations from B52 emissions are within 10% of ATSDR predictions. The B52 was used as a worst case (largest emitter) to determine if further evaluation was necessary. This indicates that the type of model used here is not important in how the results were generated.

The CHPPM also predicted air concentrations from a "more realistic" fleet of aircraft [15] which was not available to ATSDR at the time the work on this report was initiated. CHPPM's results using a fleet of planes were much lower than ATSDR's least emissions scenario using the F16 aircraft. The differences are most likely due to assumptions in the methodology used in creating emission factors for the fleet of planes. ATSDR used a similar methodology for the F16 as the B52 including F16 plane and engine specific emission factors and chemical speciation of the exhaust. CHPPM used extrapolations of the B52 speciation combined with engine specific hydrocarbon emission rates. The emission rates for each plane type are directly proportional to the modeled air concentrations. Therefore, the output is very sensitive to the emission rates that are used. ATSDR will consider the results and methodology of the CHPPM report when it becomes final.

The emission rates are a function of the engine emission rates per engine per time. The number of operations also influences these values. There is some concern that the number of operations used in this report overestimates actual operations. In this evaluation, ATSDR defined an operations as a takeoff or a landing including startup, shutdown, taxing, engine check, runway roll, take off, landing and approach [40]. Operations could include aircraft flying through airspace controlled by Kelly AFB [15] or other movements on the ground. ATSDR's approach could overestimate actual emissions.

Kelly AFB operated a second runway from the 1950s up to the mid 1960s. Modeling the emissions from this runway would reduce the maximum concentrations at the point of maximum exposure. The type of aircraft and number of operations using the second runway are not known.

Given the uncertainties inherent in the analysis, the revision would not result in changes in conclusions and recommendations from a public health perspective.

ATSDR's evaluation of air emissions from jet engine exhaust focused on benzene and 1,3-

butadiene because they contribute the great source of cancer risk. Once emitted from the jet engines these chemicals are transported with the wind and undergo transformation and degradation in the atmosphere.

Benzene and 1,3-butadiene both undergo transformation in the urban air from reactions with hydroxyl radicals (from photochemical reactions), ozone, and other atmospheric chemicals. The half-life of benzene has been measured from 1.5 hours in a “polluted air” to 5 days [19]. 1,3-butadiene is considered more reactive. Half-lives for 1,3-butadiene reported in the literature vary by the type of studies and range from 1.4 to 14.9 hours as shown below attributed to specific atmospheric components [20]:

Half Life (hours)	Description
6	By photochemical produced hydroxyl radicals
2 to 6	Photodegradation
1.4 to 1.7	By ozone (average atmospheric concentration, probably higher concentration in cities-faster degradation)
15 to 16	Triplet Oxygen (average atmospheric concentration)
14.9	Night time degradation from the average atmospheric nitrate radicals concentration

ATSDR evaluated the significance of the degradation by modeling jet emissions of 1,3-butadiene using a 1-hour half-life and a 9-hour half-life. These half lives values were used based on a report by the California Air Resources Board that stated "[a]tmospheric half-lives of 1 to 9 hours are expected." [50]. This range was reasonable to evaluate as 1 hour was near the lower end reported. 9-hours was reasonable to use as a higher value because it is in the range of the higher values. The results show that higher half-lives would not significantly change the concentrations near the base where the population of interest resides because the travel time of air emissions is much faster than 9-hours or 540 minutes (Figure A-1 demonstrated this for hexavalent chromium). The model was run with no degradation as a worst case.

Using an average of the air dispersion modeling results with half-lives of 1 and 9 hours, the general effect is to move the northern edge of the 1E-4 contour line about 0.4 miles closer to the base. The northern edge of this contour is about 1 mile north of the Kelly AFB boundary that lines up with U.S. Interstate 10. With an average half-life (5 hours), the contour line would become about 0.6 miles from the base. This movement or contraction of the risk contour becomes smaller the closer to the emission source which is the runway and taxiway in this case. **The changes in the half-live would not result in changes in conclusions and recommendations from a public health perspective.**

Results of air dispersion modeling and conclusions about estimated levels of individual contaminants.

Results

ATSDR performed an air dispersion model to estimate potential levels of contaminants in the community. As addressed earlier, ATSDR does not have information on all of the aircraft that performed takeoffs and landings at Kelly AFB. ATSDR modeled emissions from aircraft for which information on emissions could be located and ATSDR considers to be representative of a range of potential emissions from different aircraft. ATSDR modeled emissions from an F16 aircraft and a B52H aircraft to attempt to approximate the range of potential emissions. An F16 has one engine and a B52H has eight engines. The B52H emissions were considered the worst-case emissions. Benzene, 1,3-butadiene, and formaldehyde were identified as contaminants of concern from worst-case modeling of B52H emissions. The predicted levels of benzene and 1,3-butadiene from air modeling of the emissions from a B52H aircraft are shown in Figures B-2 and B-3, respectively. The predicted levels of 1,3-butadiene from air modeling of the emissions from a F16 are shown in Figures B-4a and B-4b and for benzene in Figures B-5a and B-5b. (Figures B-4a and B-5a use a afterburner stage 1 emissions factor during engine runup. Figures B-4b and B-5b use 100% power setting emissions factor during engine runup.)

Location of maximum formaldehyde levels are not shown but are located at the same locations as benzene and 1,3-butadiene maximums. ***All estimated off-base contaminant levels were below levels where health effects have been reported in the scientific literature. Community exposures of modeled annual average concentrations were below levels of concern for acute and chronic noncancer health effects, except for potentially irritating or exacerbating respiratory effects from exposure to formaldehyde. These effects are likely short-term and possibly periodic depending on the changing level of aircraft operations. Benzene, 1,3-butadiene, and formaldehyde were the only chemicals of concern for an estimated increase in cancer risk.***

Formaldehyde is produced during combustion of fossil fuels and is also endogenously produced by cellular respiration. While formaldehyde is considered a nasal cavity carcinogen in animals at high doses, evidence in humans is limited. Some epidemiological studies have associated formaldehyde exposure in industrial workers with site specific respiratory cancers while another suggests an increased risk for leukemia [21, 51–53]. Some epidemiological studies also suggest an increased risk for hematopoietic cancers in medical workers and embalmers [22]. Exposure to worst-case conditions during the period of elevated aircraft operations resulted in an increase in the risk for developing cancer for that period of time. Continuous exposure is averaged over a year because data is not available to more discretely define the exposure. It is possible that exposures occurred to higher levels for shorter periods of time, much like an occupational exposure. The Occupational Safety and Health Administration (OSHA) permissible exposure levels (PELs) are presented for perspective, which describe levels at which workers may be exposed for 8 hours per day for 5 days per week (Table B-8).

The cancer risks for 1,3-butadiene reflect a low to moderate increase in risk, depending on the cancer slope factor and the aircraft used as a source of emissions for input in the air modeling. The greatest variable is the use of an appropriate cancer slope factor used to calculate an estimate

of risk. The human-derived cancer slope factor for 1,3-butadiene was based on only one study with human data. Although ATSDR gives preference to human-derived values over animal-derived values, the uncertainty in this derivation promotes little confidence in the sole use of this value. ATSDR presented both slope factor values (animal-derived and human-derived) in risk calculations using both F16 and B52H emissions. The resulting risk estimates differed by over 2 orders of magnitude, which illustrates the degree of uncertainty. Table B-8 shows the estimated maximum risk from a continuous off-base exposure to modeled concentrations estimated for 20 years prior to 1973 using maximum operations (336,000/year) and 20 years after and including 1973 (using 112,000 operations/year) to 1994, when JP-8 jet fuel replaced JP-4 jet fuel. Continuous exposure to maximum average concentrations reflects the conservative nature of these estimates. Using a worst-case scenario is likely to overestimate the actual risk.

Benzene risk ranged from low to no apparent increase in risk, depending on the aircraft used as a source of emissions in air modeling. The cancer slope factor for benzene is less uncertain than with 1,3-butadiene as the information for the slope factor was available from several different human studies. ATSDR has developed suggested guidelines which are used to evaluate benzene exposures in air [54]. If the exposure is less than 32 $\mu g/m^3$, ATSDR assumes there is no apparent public health hazard. If exposures occur between 32 $\mu g/m^3$ and 320 $\mu g/m^3$, ATSDR evaluates these on a site-by-site basis. An exposure greater that 320 $\mu g/m^3$ may be considered a potential health hazard. Although the estimated levels of benzene were below levels at which ATSDR would have public health concerns, the uncertainty in the available data and the elevation of leukemia incidence in ZIP Codes 78227, 78237, and 78226 (1990–1994) indicate that further evaluation is warranted. **ATSDR's evaluation on leukemia can be located in the Health Outcome Data Evaluation Health Consultation [25].**

Discussion
1,3-butadiene, benzene, and formaldehyde were the chemicals generating the highest cancer risk. These levels of chemicals are below levels where health effects have been reported in workers.

Workers are considered the healthiest subpopulation of the general population. The Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) regulate the level of contaminant to which workers can be exposed and not be expected to develop adverse health effects (see Table B-8, Worker Exposure Levels). Scientists often do not know at what level more susceptible individuals of the general population might develop health effects, as most information comes from animal studies or epidemiological studies of workers.

Noncancer health effects usually exhibit a threshold effect below which adverse health effects are unlikely. For noncancer health effects, ATSDR develops comparison values (minimum risk levels [MRLs]), which are below threshold levels at which even the more susceptible individuals in the population are more likely to develop health effects. **Noncancer health effects have not been reported in the scientific literature at the average annual contaminant levels estimated to have been present in the community around Kelly AFB. Data is not available to evaluate excursions from the annual average. ATSDR used the maximum off-base annual average for evaluation.**

Most scientists assume that there may be no threshold for the initiation event in the development of cancer. Most cancers have been studied in groups of people like workers. Scientists predict the probability of developing cancer mostly from these epidemiological studies of workers and from animal laboratory studies. Because cancers often involve long latency periods, it may be 10–30 years before the cancers are diagnosed, so scientists express the risk of developing cancer through a risk assessment. Each individual has a different risk because each individual has different risk factors, including genetics, illness, diet, environmental exposures, occupational exposures, and home exposures. The scientist cannot predict who may or may not develop cancer from an environmental exposure because the scientist cannot know the risk factors for each individual. The risk expressed by the scientist refers to the upper bound risk for an individual in the general population, but the individual's actual risk is unknown. An individual's actual risk may be as low as zero or may be somewhat higher than the estimated risk. Risk assessment is used to describe the *relative* degree of hazard from an exposure, but may not be strictly applicable to the individual that was exposed.

Figures B-6 and B-7 depict levels of interest for benzene and 1,3-butadiene, respectively, and the corresponding risk estimates. Levels of benzene in the community estimated by modeling air emissions are

- in the low risk range,
- similar to the overall national exposure, and
- about 20–30 times less than levels where health effects have been reported.

Levels of 1,3-butadiene in the community estimated by modeling base air emissions are

- in the low to moderate risk range,
- near levels found in a smoke-filled bar,
- less than found around petrochemical plants, and
- about 100 times less than levels where health effects have been reported.

Levels of formaldehyde in the community estimated by modeling base air emissions are

- in the low risk range,
- similar to residential indoor air in conventional homes,
- less than residential indoor air in mobile homes, and
- about 10 times less than levels were health effects have been reported.

Exposures at these levels represent estimates of exposure only to emissions from Kelly AFB. These estimates do not include potential benzene, 1,3-butadiene, and formaldehyde exposure to emissions from other sources, such as automobile and other industrial emissions, and building materials. A person's total exposure may include inhalation of benzene, 1,3-butadiene, and formaldehyde from other sources. ATSDR used the *maximum* off-base annual average concentrations for evaluation.

Figure B-8 is included for comparison and depicts the location and magnitude of the cumulative risk from exposure to *current* (1995 and after) air emissions and *current* (1995 and after) industrial emissions. Current aircraft emissions are an average of the B52 and F16 emissions using JP-8 jet fuel and current level of operations (60,000 operations per year).

Table B-8. Estimated maximum past off-base average annual ambient air concentrations from stationary and aircraft emissions.

Chemical	Scenario	Maximum Off-base Concentration (µg/m^3) [c]		Chronic Non-Cancer Comparison Value (µg/m)	Cancer Comparison Value (µg/m^3)	Worker Exposure Limit (µg/m^3)	Estimated Cancer Risk	
		before 1973	1973 to 1994				before 1973	1973 to 1994
1,3-butadiene	F16 human data [a]	10 [4.4][j]	3 [1.5]	NA	0.004 [e]	2200 [d]	1E-05 [8E-06]	4E-06
1,3-butadiene	F16 animal data [b]	10 [4.4]	3 [1.5]	NA			8E-04 [4E-04]	2E-04
1,3-butadiene	B52 human data	20	7	NA			3E-05	9E-06
1,3-butadiene	B52 animal data	20	7	NA			2E-03	6E-04
benzene	F16 human data [f]	10 [4.5]	3 [1.5]	13 [h] intermediate	0.1 [e]	320 [g]	2E-05 [2E-05]	7E-06
benzene	B52 human data	20	7	13 [h] intermediate			5E-05	2E-05
formaldehyde	B52	58	19	10 [h]	0.08 [k]	922 [d]	2E-04	7E-05
acetaldehyde	B52	5	2	9 [i]	0.5 [k]	360,000 [h]	3E-06	1E-06
naphthalene, methyl-naphthalenes	B52	16	5	10 [h]	-	50,000 [g]	-	
acrolein	B52	4.2	1.4	0.02 [i]	-	250 [g]	-	

NA Not Available

a Cancer Slope Factor (4.3E-6/µg/m^3) derived from human data [External Review Draft - Health Risk Assessment of 1,3-Butadiene. US EPA. NCEA-W-0267. January 1998. National Center for Environmental Assessment. Office of Research and Development. Washington, DC.]. All risk estimates assume continuous 20 year exposures before 1973 and continuous 20 year exposures from 1973 to 1994 to the maximum annual average concentrations for each era and 336,000 operations/year before 1973 and 112,000 operations/year from 1973 to 1994.

b Cancer Slope Factor (0.00028/µg/m^3) derived from animal data [IRIS].

c µg/m^3 micrograms per cubic meter of air

d Occupational Safety and Health Administration Permissible Exposure Level.

e ATSDR Cancer Risk Evaluation Guide

f Cancer slope factor 7.8E-06 µg/m^3 (EPA IRIS)

g National Institute for Occupational Safety and Health Time Weighted Average.

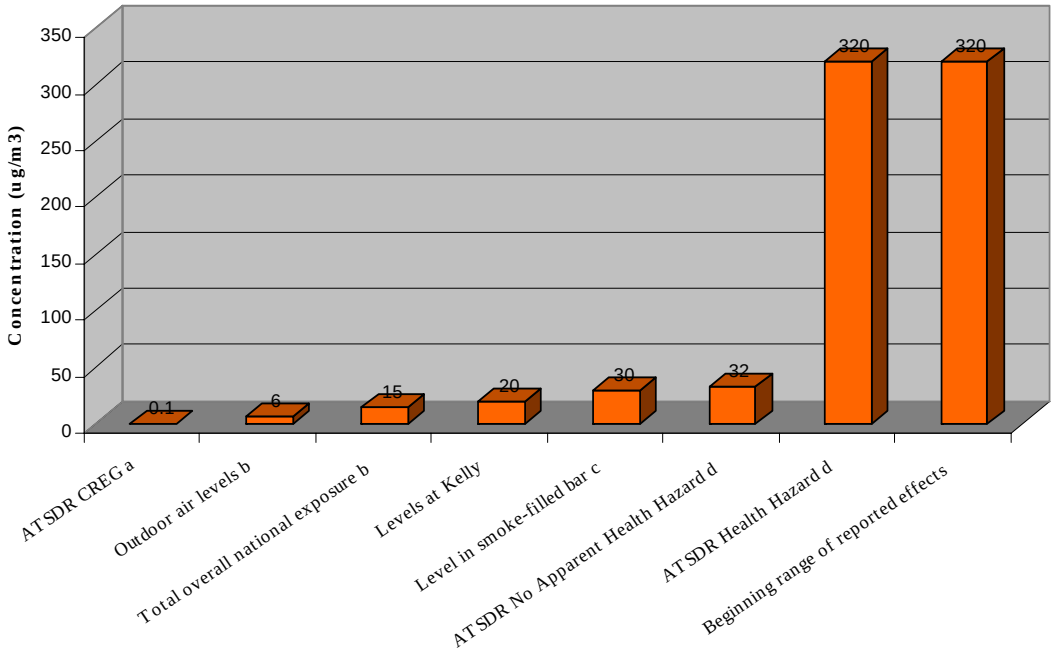
h ATSDR Minimum Risk Level

i EPA Inhalation Reference Concentration (RfC).

j. These concentrations are estimates based on using an engine setting of 100% power (military setting) during engine check. The other concentrations and cancer risk estimates are based on an engine setting of afterburner stage 1.

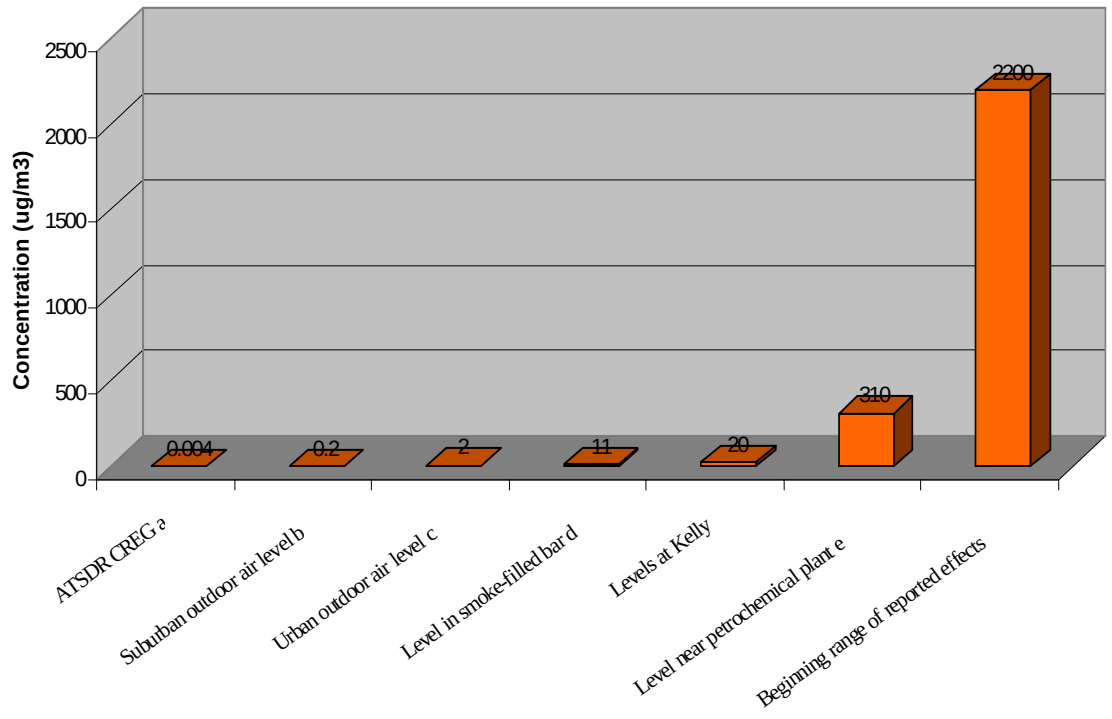
k. EPA Cancer slope factors from IRIS. Formaldehyde : 0.000013/µg/m^3 from animal data, as no human data is available; Acetaldehyde: 2.2E-06/µg/m^3 from animal data, as no human data is available.

Figure B-6
Comparative Levels of Benzene



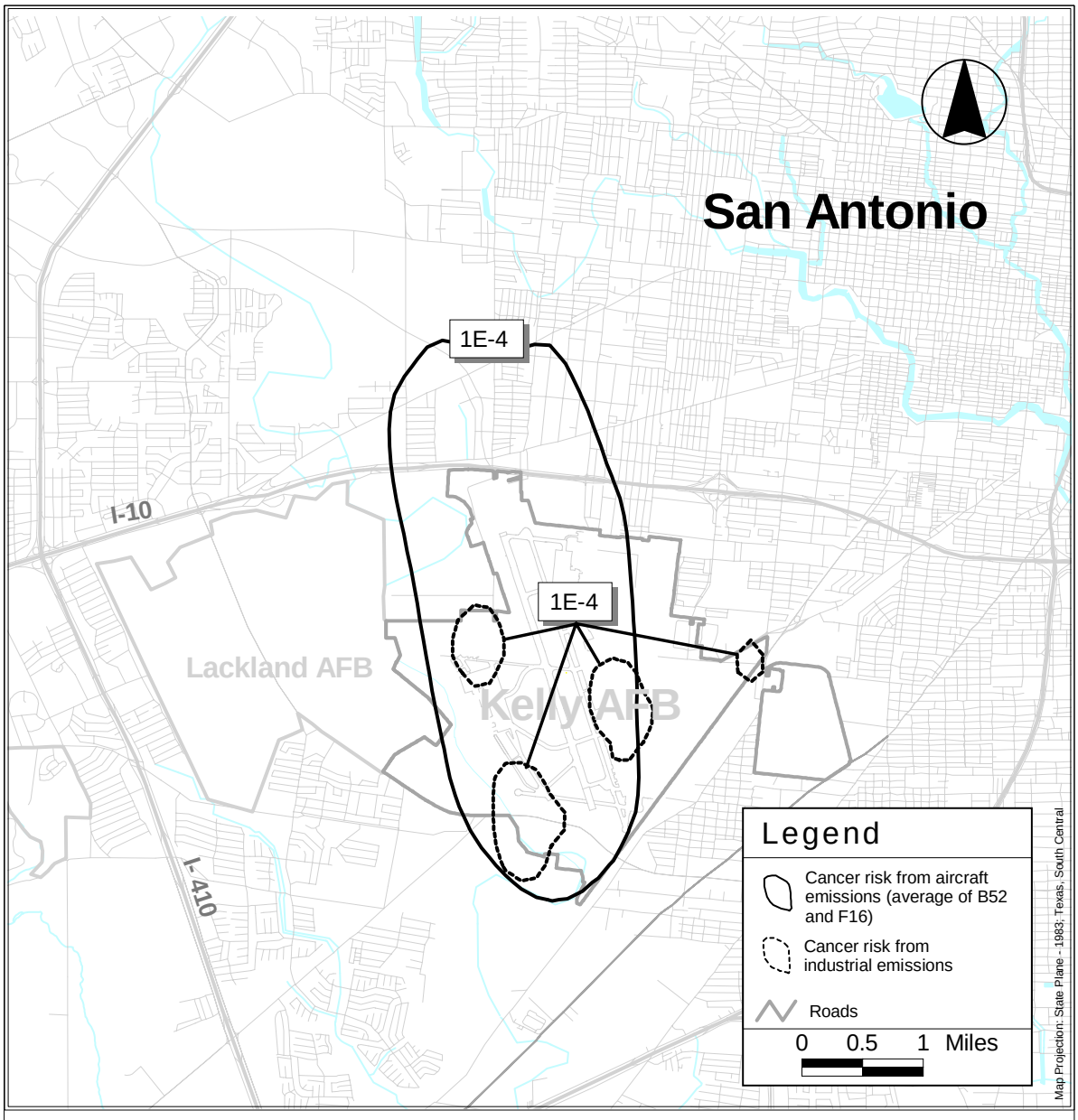
a ATSDR CREG (Cancer Risk Evaluation Guide)
b Wallace, LA. 1989. Major sources of benzene exposure. Environ Health Prospect 82:165–169.
c Brunnemann KD, Kagan MR, Cox JE, et al. 1989. Determination of benzene, toluene and 1,3-butadiene in cigarette smoke by GC-MSD. Exp Pathol 37:108–113.
d ATSDR draft guidelines for benzene (Division of Health Assessment and Consultation).

Figure B-7
Comparative Levels of 1,3-Butadiene



a ATSDR CREG (Cancer Risk Evaluation Guide)
b Airometric Information Retrieval System. 1994. San Antonio, TX.
c Airometric Information Retrieval System. 1988. Houston, TX.
d Brunnemann KD, Kagan MR, Cox JE, et al. 1990. Analysis of 1,3-butadiene and other selected gas-phase components in cigarette mainstream and sidestream smoke by gas chromatography-mass selective detection. Carcinogenesis 11:1863.
e Texas Air Control Board. 1990. Written communication to Bill Henriques (ATSDR), regarding 1,3-butadiene concentrations in air. Austin, Texas.

Figure B-8



COMPARISON OF CUMULATIVE CANCER RISK FROM CURRENT AIRCRAFT AND INDUSTRIAL AIR EMISSIONS

Kelly Air Force Base, San Antonio, Texas

Bexar County, Texas

Base Map Source: 1995 TIGER/Line Files, Site Boundary Source: Kelly AFB, 1995 Emissions Location and Amount Source: Kelly AFB, Health Risk Source: ATSDR(DHAC). Emissions were modeled with EPA's ISCST3 air model and inhalation slope factors from U.S. EPA Region 6 were applied to output to arrive at health risk.

BCK2 090302

Appendix B
Attachments

Appendix B, Attachment 1

Emission rates and locations of past stationary air emissions.

Building Number	Easting (meters)	Northing (meters)	Emission Rate (g/s)
Benzene			
BLDG_003	643403.44	4171958.25	3.716963E-04
BLDG_009	642750.25	4171896.25	7.666236E-04
BLDG_036	642130.06	4170109.0	1.215643E-08
BLDG_053	641198.88	4169204.75	4.706397E-05
BLDG_062	641198.88	4169204.75	2.416111E-05
BLDG_063	640863.15	4169672.55	2.013426E-05
BLDG_065	640544.69	4169687.13	4.108452E-03
BLDG_082	639870.56	4170894.0	5.808811E-05
BLDG_086	639651.5	4171084.25	1.013861E-05
BLDG_089	639689.0	4171134.75	1.977116E-06
BLDG_096	642721.25	4171791.25	1.678367E-05
BLDG_098	639679.5	4172361.5	7.544674E-08
BLDG_114	640029.56	4172104.5	1.990896E-05
BLDG_142	641055.81	4172696.5	2.519330E-05
BLDG_159	641769.35	4173519.08	2.643540E-07

Building Number	Easting (meters)	Northing (meters)	Emission Rate (g/s)
1,3-Butadiene			
BLDG_655	640544.69	4169687.13	1.580000E-02

Building Number	Easting (meters)	Northing (meters)	Emission Rate (g/s)
Chromium-Sources used in sensitivity analysis			
BLDG_030	642041.27	4171147.04	2.241729E-04
BLDG_032	642461.19	4170806.06	1.807650E-04
BLDG_033	642293.13	4170746.0	8.631835E-07
BLDG_036	641652.64	4171415.92	4.574073E-04
BLDG_037	641799.0	4170576.0	2.100413E-04
BLDG_038	643401.38	4171946.25	2.100413E-04
BLDG_053	641198.88	4169204.75	4.791997E-06
BLDG_064	640479.69	4169650.75	2.877278E-05
BLDG_065	640544.69	4169687.13	6.252336E-04
BLDG_082	639870.56	4170894.0	3.740462E-05

Building Number	Easting (meters)	Northing (meters)	Emission Rate (g/s)
Chromium-Sources used in sensitivity analysis			
BLDG_114	640029.56	4172104.5	1.086371E-05
BLDG_205	638908.31	4170765.0	2.913244E-05

Building Number	Easting (meters)	Northing (meters)	Emission Rate (g/s)
Ethylene Benzene			
BLDG_003	643403.438	4171958.250	1.0624e-04
BLDG_004	643516.438	4172127.500	3.9676e-05
BLDG_008	643160.375	4171753.250	3.4500e-06
BLDG_009	642750.250	4171896.250	2.1913e-04
BLDG_030	642039.062	4171204.250	1.7250e-06
BLDG_032	642529.188	4170732.000	7.3314e-05
BLDG_035	642120.062	4170665.000	6.9000e-06
BLDG_036	642130.062	4170109.000	1.9200e-07
BLDG_037	641799.000	4170576.000	2.9325e-05
BLDG_038	643401.375	4171946.250	2.9325e-05
BLDG_053	641200.875	4169207.750	1.3700e-06
BLDG_062	640798.750	4169691.750	8.0200e-07
BLDG_063	640866.750	4169669.750	8.0200e-07
BLDG_064	640479.688	4169650.750	1.7250e-06
BLDG_065	640542.688	4169685.750	5.1440e-06
BLDG_082	639870.562	4170894.000	3.7088e-05
BLDG_086	639651.500	4171084.250	2.8979e-06
BLDG_089	639690.500	4171132.250	1.1680e-10
BLDG_094	638908.312	4172108.500	8.6300e-07
BLDG_096	642721.250	4171791.250	4.7970e-06
BLDG_098	639694.500	4172342.500	4.3500e-07
BLDG_114	640029.562	4172104.500	7.0581e-10
BLDG_142	641055.812	4172696.500	7.0581e-10
BLDG_159	641624.000	4173499.750	7.0581e-10
BLDG_205	638908.312	4170765.000	3.4500e-06

Building Number	Easting (meters)	Northing (meters)	Emission Rate (g/s)
Methyl Ethyl Ketone			
BLDG_005	643305.375	4171849.250	2.7332e-03
BLDG_008	643160.375	4171753.250	5.1050e-02
BLDG_030	642185.594	4171098.625	8.9946e-02
BLDG_032	642529.188	4170732.000	8.6238e-01

Building Number	Easting (meters)	Northing (meters)	Emission Rate (g/s)
Methyl Ethyl Ketone			
BLDG_033	642133.062	4170778.000	6.6980e-04
BLDG_035	642120.062	4170665.000	2.4310e-03
BLDG_036	641786.000	4171156.200	4.7493e+00
BLDG_037	641799.000	4170576.000	1.2422e+00
BLDG_038	643401.375	4171946.250	8.1559e-01
BLDG_052	641148.344	4169358.750	2.1636e-01
BLDG_064	640468.355	4169635.083	4.7404e-02
BLDG_082	639898.562	4170929.333	5.4028e-01
BLDG_090	639360.407	4171818.750	1.0908e-01
BLDG_094	638908.312	4172108.500	1.0028e-02
BLDG_141	642695.250	4171616.250	3.6464e-03
BLDG_142	641066.812	4172716.500	1.8232e-02
BLDG_205	638908.312	4170765.000	1.9752e-02

Building Number	Easting (meters)	Northing (meters)	Emission Rate (g/s)
Methylene Chloride			
BLDG_032	642529.188	4170732.000	0.810127767
BLDG_033	642268.125	4170467.000	0.012274663
BLDG_035	642120.062	4170665.000	0.024549326
BLDG_036	641740.000	4171439.250	2.172615401
BLDG_037	641810.500	4170497.500	69.750773318
BLDG_038	643401.375	4171946.250	1.687766181
BLDG_062	640817.750	4169672.667	2.780635652
BLDG_063	640863.150	4169672.550	2.317196381
BLDG_064	640468.355	4169635.083	4.05063884
BLDG_082	639870.562	4170894.000	0.699655799
BLDG_142	641066.812	4172716.500	0.024549326
BLDG_005	643305.375	4171849.250	0.009974559
BLDG_030	642035.062	4171149.750	10.2891548
BLDG_032	642516.188	4170779.000	12.24327768
BLDG_036	641616.438	4171349.250	8.955193021
BLDG_037	641850.000	4170618.000	8.583610039
BLDG_062	640817.750	4169672.667	1.537964586
BLDG_063	640863.150	4169672.550	1.281637078

Building Number	Easting (meters)	Northing (meters)	Emission Rate (g/s)
Tetrachloroethylene (PCE)			
BLDG_005	643305.375	4171849.250	0.009974559
BLDG_030	642035.062	4171149.750	10.2891548

Building Number	Easting (meters)	Northing (meters)	Emission Rate (g/s)
Tetrachloroethylene (PCE)			
BLDG_032	642516.188	4170779.000	12.24327768
BLDG_036	641616.438	4171349.250	8.955193021
BLDG_037	641850.000	4170618.000	8.583610039
BLDG_062	640817.750	4169672.667	1.537964586
BLDG_063	640863.150	4169672.550	1.281637078
Building Number	**Easting (meters)**	**Northing (meters)**	**Emission Rate (g/s)**
Toluene			
BLDG_003	643403.438	4171958.250	0.0027391
BLDG_004	643516.438	4172127.500	0.0022311
BLDG_005	643305.375	4171849.250	0.00022168
BLDG_008	643160.375	4171753.250	0.00089195
BLDG_009	642750.250	4171896.250	0.0056494
BLDG_030	642185.594	4171098.625	0.003671
BLDG_032	642469.167	4170769.000	0.0082629
BLDG_033	642268.125	4170467.000	0.00055778
BLDG_035	642120.062	4170665.000	0.0017771
BLDG_036	641889.825	4170925.950	0.011377
BLDG_037	641799.000	4170576.000	0.011298
BLDG_038	643401.375	4171946.250	0.011117
BLDG_053	641198.875	4169204.750	6.2955E-5
BLDG_062	640817.750	4169672.667	7.2377E-5
BLDG_063	640863.150	4169672.550	6.0314E-5
BLDG_064	640468.355	4169635.083	0.005487
BLDG_065	640544.688	4169687.125	0.0054956
BLDG_082	639870.562	4170894.000	0.0058632
BLDG_086	639651.500	4171084.250	7.4713E-5
BLDG_089	639689.000	4171134.750	1.457E-5
BLDG_094	638908.312	4172108.500	0.0001816
BLDG_096	642721.250	4171791.250	0.00012368
BLDG_098	639679.500	4172361.500	4.2102E-6
BLDG_114	640029.562	4172104.500	2.6434E-5
BLDG_141	642695.250	4171616.250	2.5943E-5
BLDG_142	641061.312	4172706.500	0.00091206
BLDG_159	641769.354	4173519.083	6.3239E-6
BLDG_205	638908.312	4170765.000	0.00048643

* Final Report. Historical Air Emissions Estimate. Kelly AFB, TX. EARTH TECH, Inc. San Antonio, TX. March 27, 2000.

Appendix B, Attachment 2

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE FOR ENVIRONMENT, SAFETY AND OCCUPATIONAL HEALTH RISK ANALYSIS (AFMC)
BROOKS AIR FORCE BASE TEXAS

13 February 2001

MEMORANDUM FOR AFBCA/DK
ATTENTION: MR CHARLES WILLIAMS

FROM: AFIERA/RSRE
2513 Kennedy Circle
Brooks AFB, TX 78235-5123

SUBJECT: Consultative Letter, IERA-RS-BR-CL-2001-0011, Availability of Information Related to Unburned Fuel and Oil Misting Emissions From Aircraft Takeoffs and Landings

1. The Agency for Toxic Substances and Disease Registry (ATSDR) requested available information related to emissions from aircraft takeoffs and landings. This information is needed to address community and ATSDR public health concerns related to aircraft fuel and oil misting. The specific question posed by ATSDR was whether any available data exists on sampled or modeled unburned fuel or oil mist emissions during takeoffs and landings.

2. We contacted the Federal Aviation Administration (FAA) and several organizations within the US Air Force (USAF): Robert Holsclaw, FAA, Environmental Section, Maj Jeanette Howard, Air Quality Branch (AFIERA/RSEQ), Maj Brian Blazicko (AFIERA/RSHI), and Carry Embree, Propulsion Environmental Working Group Member (OC-ALC/LR). No information was available from these groups related to quantitative analyses of aircraft fuel or oil misting (Wade, 2001). Three recently accomplished studies qualitatively describe fuel and oil misting, as referenced in four documents: Massport International (1997), Hoffnagle et al.(1997), KM Chng Environmental Inc.(1997), and KM Chng Environmental Inc.(1999) (Attachments 1-4). These studies were initiated in response to assertions from residents and government officials that aircraft using O'Hare and Logan airports caused the deposition of soot, particles or oily film on surfaces in communities near these airports. Hoffnagle et al.(1997), KM Chng (1997; 1999), and Massport International (1997) conclude that deposited particles monitored near the airports bore little resemblance to either unburned jet fuel or soot from jet exhaust.

3. ATSDR specifically asked us to obtain information related to unburned JP-8 aerosol exposure to ground crews during cold-engine start conditions. Maj Blazicko (2001) provided the following information regarding these evaluations:

a. The AF Institute for Environment, Safety, and Occupational Health Risk Analysis/Industrial Hygiene Branch's (AFIERA/RSHI) initial testing determined that existing sampling methods were inadequate to properly characterize the exposure due to the volatile nature of the JP-8 aerosol.

b. A current AFIERA/RSHI research effort with the University of North Carolina (Demonstration of Sampling Method for JP8 Aerosols; Contract F41622-97-C-0025) was established to develop and employ a methodology to evaluate ambient JP8 concentrations of aircraft emissions at temperatures of 0°F and below. The UNC study will be completed in the last quarter of 2001. This information is designed for

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Appendix B, Attachment 2

incorporation into an occupational health risk assessment of ground crews and includes no information on takeoffs and landings.

4. Joe Franzello, Brooks AFB Technical Library, assisted us in querying several databases to determine the availability of information related to emissions of unburned fuel and oil misting from aircrafts. The following databases and keywords were used:

Database	Keywords
FirstSearch	aircraft and oil mist aircraft and unburned fuel aircraft and soot and exhaust aircraft and carbon black
DialogTech	Aerosol or atomic or spray or mist and fuel or JP

No quantitative information was located as a result of these searches (Attachment 5).

5. Evaluations of ground crew exposures may not indicate unburned fuel or oil misting levels, but may assist ATSDR in evaluating their emission models due to the proximity of the ground crews to aircraft taxiing, takeoffs, and landings. Ground crew exposures to F-15, KC-135, and C-130 aircraft engine exhaust were evaluated through three studies (Johnston and Fritts, 1999a; Johnston and Fritts, 1999b; and Johnston and Lazenby, 1999, Attachments 6-8). Personal samples were collected from ground crew chiefs who are responsible for preparing aircraft for launch and, upon recovery, performing post-flight check procedures. Analyses included aldehydes, BTEXs (benzene, toluene, ethyl benzene, and xylenes), gases (carbon monoxide, nitric oxide, nitrogen dioxide, sulfer dioxide), JP-8 fuel (as naphthas), and polynuclear aromatic hydrocarbons (particulate and vapor fraction). Several aldehydes analyses were quantifiable. All other results were below their respective detection limits.

6. If you have any comments or questions, please call Mr Jody Wireman at (210)536-6123 or Mr Cornell Long at (210)536-6121.

JODY R. WIREMAN
Environmental Scientist
Environmental Sciences Branch

Attachments:
1. Massport International, 1997 (2 copies)
2. Hoffnagle et al., 1997 (2 copies)
3. KM Chng Environmental Inc., 1997 (2 copies)
4. KM Chng Environmental Inc., 1999 (2 copies)
5. Literature Search Results (2 copies)
6. Johnston and Fritts, 1999a (2 copies)
7. Johnston and Fritts, 1999b (2 copies)
8. Johnston and Lazenby, 1999 (2 copies)
9. References (2 copies)

Attachment 9 - References

Blazicko, 2001. Blazicko B. Personal communications about JP-8 cold engine startup occupational exposure research project. January 31, 2001.

DialogTech, 2001. DialogTech. http://www.dialogselect.com/tech/ January 22, 2001.

FirstSearch, 2001. FirstSearch. http://www.oclc.org/firstsearch/ January 23, 2001.

Hoffnagle et al., 1997. Hoffnagle GF, Cooper JA, and Morris S. Soot Deposition Study: Logan Airport and Surrounding Communities. TRC Environmental Corporation, January 1997.

Johnston and Fritts, 1999. Johnston DS and Fritts GD. Consultative Letter, IERA-RS-BR-CL-1999-0008, Engine Exhaust Exposure of F-15 Crew Chiefs, Otis ANGB, MA. February 12, 1999.

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KM Chng Environmental Inc., 1997. KM Chng Environmental Inc. Soot Deposition Study: Logan Airport and Surrounding Communities. January 1997.

KM Chng Environmental Inc., 1999. KM Chng Environmental Inc. Findings Regarding Source Contributions to Soot Deposition: O'Hare International Airport and Surrounding Communities. December 1999.

Massport International, 1997. Massport International. Summary of Two Logan Soot Studies. January 1997.

Wade, 2001. Wade M. Personal communications about aircraft oil and fuel misting. AFIERA/RSEQ (Karta Technologies). January 19, 2001.