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July 17, 2007

Mr. James S. Adams, MA
Environmental Office, MS 40
California Energy Commission
1516 9th Street
Sacramento, California 95814-5504

Subject: Staff Assessment-Russell City Energy Center

Dear Mr. Adams:

The Aircraft Owners and Pilots Association (AOPA) represents the general aviation interests of 412,000 members, more than two-thirds of the nation's pilots, including over 50,000 members in the State of California. AOPA is committed to ensuring the future viability and economic development of general aviation airports and their facilities as part of the state and national transportation system. Any development that threatens the safety of aircraft operating near airports can be considered a threat to the viability of a local airport and the national aviation transportation system. This is especially true in highly developed metropolitan areas such as the San Francisco Bay area and Hayward, California.

While the Association can understand the need to meet the ever-growing demands for electric energy in Northern California and Hayward, based on the information we have reviewed regarding the above referenced project, AOPA is strongly opposed to approval and construction of the Russell City Energy Center at the currently proposed location which is roughly one mile from Hayward Executive Airport (HWD). HWD, with over 477-based aircraft and nearly 125,000 operations each year, is a major reliever airport in the Bay Area.

We believe that the Staff Assessment clearly demonstrates and identifies a number of potential safety impacts to aviation operations and that thermal plumes generated by the facility could create hazards to aircraft operating into and out of the Hayward Executive Airport. We are particularly concerned that while local pilots may be familiar with the facility if it is constructed, over flights from transient aircraft unfamiliar with the facility will occur.

Additionally, during certain atmospheric conditions, vapor plumes created by this plant will create turbulent conditions for aircraft that over fly the site either on approach to HWD or another airport in the same geographic area. Such vapor plumes will also have an impact on visual navigation equipment used for navigation to the airport under either visual or instrument conditions.

A similar gas turbine generation facility is located approximately the same overall distance (approximately 1 mile) from the Blythe, California airport. Our members have reported to us the same detrimental effect on their ability to land safely at that airport. Aircraft have experienced flight "upsets" due to turbulence encountered while over flying the exhaust stacks of that facility. It is our understanding that a number of mitigation measures promised by the proponent of the Blythe site was never implemented as promised.

The FAA Flight Procedure Standards Branch, AFS-400, has issued a report on "Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes." In January 2006, this study was issued as a report and published under Safety Study Report DOT-FAA-AFS-420-06-1.

In summary, the report indicated:

> *The underlying presumption is that high efflux temperature or velocity from industrial facilities may cause air disturbances via exhaust plumes. Two hazards were identified during brainstorming sessions by members of the safety risk analysis team. The first hazard recognized turbulence that may be associated with plumes that could result in possible airframe damage and/or negative affects on aircraft stability in flight. The second hazard discussed was the possible adverse effects of high levels of water vapor, engine/aircraft contaminants, icing, and restricted visibilities produced by these plumes. These hazards taken individually or cumulatively, could possibly result in the loss of the aircraft or fatal injury to the crew, as well as substantial damage to ground facilities. The SME team considered these situations to be most critical for general aviation (GA) aircraft flying at low altitudes during the takeoff and/or landing phase when an aircraft is in close proximity to an airport. The safety risk analysis team performed their analysis of the predictive risks associated with the plumes and determined the effects of the hazards as low, or in the green section of the risk matrix.*

A copy of the full report is attached to this letter.

The consequences of even one aircraft being upset by the thermal plumes and resulting in incident or accident could affect the lives of the aircraft occupants and people on the ground. Such an unfortunate occurrence would undoubtedly lead to attempts to restrict operations at the airport, or worse, attempts to close the airport.

In closing, <u>we again respectfully request that the Commission reject approval of this project</u>. While we clearly understand the need for development of energy to serve the public, we recommend another location that will not have a detrimental safety impact on aircraft operations in the Bay Area and at Hayward Executive Airport specifically.

Sincerely,

Bill Dunn
Vice President
Airports

Attachment

Safety Study Report
DOT-FAA-AFS-420-06-1

Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes

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January 2006

NOTICE

this report.

1. Report No. DOT-FAA-AFS-420-06-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle		5. Report Date

Executive Summary

The Flight Procedures Standards Branch (AFS-420), Flight Technologies and Procedures Division (AFS-400), was tasked by the Director of Flight Standards Service (AFS-1) of the Federal Aviation Administration (FAA) to perform a risk analysis of overflights of vertical exhaust plumes. These thermal *"plumes,"* visible or invisible, are generally associated with exhaust from the smoke stacks of power generating facilities, industrial production facilities, or other systems which could have the ability to release large amounts of pressurized or otherwise unstable air.

AFS-420 organized and led a safety risk analysis team consisting of FAA subject matter experts (SME) and civilian contract personnel. The SME from various disciplines including: aviation safety, risk analysis/assessment, human factors, aeronautical engineering, air traffic control (ATC), statistical analysis, and military/civil and commercial aviation, each provided a high level of experience and expertise to examine the issue. Team members are identified in Appendix A. The team determined that the FAA Safety Risk Management (SRM) methodology contained in the FAA Safety Management System (SMS) Manual would be an appropriate vehicle to perform their analysis.

The underlying presumption is that high efflux temperature or velocity from industrial facilities may cause air disturbances via exhaust plumes. Two hazards were identified by members of the safety risk analysis team. The first hazard recognized turbulence that may be associated with plumes that could result in possible airframe damage and/or negative effects on aircraft stability in flight. The second hazard discussed was the possible adverse effects of high levels of water vapor, engine/aircraft contaminants, icing, and restricted visibilities produced by these plumes. These hazards, taken individually or cumulatively, could possibly result in the loss of the aircraft or fatal injury to the crew, as well as substantial damage to ground facilities. The SME team considered these situations to be most critical for general aviation (GA) aircraft flying at low altitudes during the takeoff and/or landing phase when an aircraft is in close proximity to an airport.

The tools and analysis techniques that were used to review the hazards were the "What if" Technique and Preliminary Hazard Analysis (PHA). These tools are described in-depth in the *SMS Manual.* The SRM methodology used by the team to assess and identify safety hazards was to apply SME knowledge, experience, and expertise across the various disciplines during formal and informal review sessions.

The data sources which the team used to assess risks associated with the plume issue included: Aviation Safety Reporting System (ASRS), National Aviation Safety Data Analysis Center (NASDAC), Accident/Incident Data System (AIDS), National Transportation Safety Board (NTSB), Aviation Database & Synopses, and the

Australian Government Civil Aviation Safety Authority Advisory Circular (AC) 139-05(0) Guidelines for Conducting Plume Rise Assessments dated June 2004.

The analysis also included a review of a broad spectrum of the available safety data, regulations, and professional literature. The SME team also considered input from private citizens who had previously expressed concern with regard to the issue.

Historical statistical data analysis concluded that the accident/incident rate for overflights of exhaust plumes to be of the order of 10^{-9} or less. Since the target level of safety (TLS) for GA activities was determined to be 1×10^{-7}, the probability of an accident or incident from overflight of an exhaust plume is considerably less than the required TLS. Since the TLS is satisfied, the likelihood of an accident or incident caused by overflight of an exhaust plume is acceptably small.

The safety risk analysis team performed their analysis of the predictive risks associated with the plumes and determined the effects of the hazards as low, or in the green section of the risk matrix. As a result of this assessment, the risk associated with plumes is deemed acceptable without restriction, limitation, or further mitigation.

However, to further lower the already acceptable risk associated with the overflight of vertical plumes, the team recommended the continuance of training and awareness programs that have been successful with similar hazards of acceptable risk levels.
The safety risk assessment team recommended the following:

- Amend the Aeronautical Information Manual (AIM) Chapter 7, Section 5 with wording to the effect that overflight at less than 1,000 feet vertically above plume generating industrial sites should be avoided.

- Publish (as appropriate) the position and nature of the present power plants located near public airports in the Airport/Facility Directory (A/FD) and issue a Notice to Airmen (NOTAM) when operationally necessary.

- Where operationally feasible, make the temporary fight restriction (TFR) that includes the overflight of power plants a permanent flight restriction.

- Amend FAA Order 7400.2 to consider a plume generating facility as a hazard to navigation when expected flight paths pass less than 1,000 feet above the top of the object. Flight Standards Service will be required to provide comment for any facility not meeting this criterion.

- Amend Advisory Circular 70/7460-2K Proposed Construction of Objects that May Affect the Navigable Airspace - Change Instructions for Completing FAA Form 7460-1 – Notice of Proposed Construction or Alteration Item # 21, add:

"For structures such as power plants or any industrial facility where exhaust plume discharge could reasonably be expected and reportable under the provisions of Part 77, thoroughly explain the nature of the discharge."

These actions will serve to further enhance aviation safety within the National Airspace System.

Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes

DOT-FAA-AFS-420-06-1 January 2006

Table of Contents

List of Tables

List of Figures

1.0. Introduction

The Flight Procedures Standards Branch (AFS-420), Flight Technologies and Procedures Division (AFS-400), was tasked by the Director of Flight Standards Service (AFS-1) of the Federal Aviation Administration (FAA) to perform a risk analysis of overflights of vertical plumes. AFS-420 organized and led a safety risk analysis team (hereafter referred to as the "team") consisting of FAA subject matter experts (SME). Please see Appendix A for a list of SME team participants. The SME from various disciplines including aviation safety, risk analysis/assessment, human factors, aeronautical engineering, air traffic control (ATC), statistical analysis, and military/civil and commercial aviation provided a high level of experience and expertise to examine the issue. The team determined that the FAA Safety Risk Management (SRM) methodology contained in the FAA Safety Management System (SMS) Manual would be an appropriate vehicle to perform their analysis. This methodology includes the following:

- Description of the presumed safety issue
- Identification of potential hazards
- Risk Analysis
- Risk Assessment
- Treatment (mitigation) of the risk, if required

Note: The SRM process is usually applied for risk analysis/assessment of changes to baseline (current) facilities or procedures within the (NAS). However, AFS-420 personnel determined the SRM procedural process provided the greatest flexibility and broadest analysis for determining aviation risk for the issue at hand.

<u>Section 1</u> - Description of the Presumed Safety Issue

The underlying presumption is that high efflux temperature or velocity from industrial facilities may cause air disturbances via exhaust plumes that would have the potential to cause airframe damage and/or negatively affect the stability of aircraft in flight. Associated hazards could include: high levels of water vapor, icing, restricted visibilities, engine/aircraft contaminants. These hazards taken individually or cumulatively, could possibly result in the loss of the aircraft or fatal injury to the crew, as well as substantial damage to ground facilities. The team considered these situations to be most critical for general aviation (GA) aircraft flying at low altitudes during the takeoff and/or landing phase when an aircraft is in close proximity to an airport. These thermal *"plumes,"* visible or invisible, are generally associated with exhaust from the smoke stacks of power generating facilities, industrial production facilities, or other systems which could have the ability to release large amounts of pressurized or otherwise unstable air. Research has been accomplished by the Australian Government Civil Aviation Safety Authority (CASA) on plume rise velocities versus aircraft upset. The United States Environmental Protection Agency (EPA) plume rise models are, for the most part, models of plume dispersion and heat/velocity measures that do not provide any analysis on the effect of aircraft overflight.

Section 2 - Review of Safety Data/Literature and Identification of Potential Hazards

The review of safety data and associated literature obtained from various sources included the following:

- National Aeronautics and Space Administration (NASA), Aviation Safety Reporting System (ASRS)
- Federal Aviation Administration (FAA), National Aviation Safety Data Analysis Center (NASDAC), Accident/Incident Data System (AIDS)
- National Transportation Safety Board (NTSB) Aviation Database & Synopses
- Aeronautical Information Manual (AIM), Change 3, August 4, 2005
- Title 14 Code of Federal Regulations (CFR) with specific attention to: Part(s) 77 - *Objects Affecting the Navigable Airspace,* Part 91.13 - *Careless or Reckless Operation,* and Part 91.119 - *Minimum Safe Altitudes: General*
- Federal Aviation Administration Safety Management System Manual, Version 1.1, May 21, 2004
- Australian Government Civil Aviation Safety Authority Advisory Circular (AC) 139-05(0, Guidelines for Conducting Plume Rise Assessments dated June 2004 was reviewed. (Note: this information was used as professional reference material as the FAA does not necessarily agree or disagree with the guidance contained in the AC)

2.0. Discussion

The salient points discussed during the SMS brainstorming sessions at AFS-420 in Oklahoma City, Oklahoma, by the risk analysis team included, but were not limited to:

(1) Aviation Database Queries Regarding Overflight of Vertical Plumes

A database search of NASA ASRS records using various key words such as: *plumes, power plants, smoke stacks, nuclear, industrial power plants, power plant - aircraft – turbulence, smokestack(s), updrafts, downdrafts* and similar combinations was conducted and reviewed. The results of over 671,006 NASA ASRS pilot reports gathered over 30 a year period indicated zero pilot-reported overflight incidents with exhaust plumes from facilities such as power plants.

A similar search of the NASDAC AIDS (FAA) accident/incident database records search (approximately 150,000 records) indicated no accidents and one possible, yet not confirmed, helicopter incident in 1979. Additionally, there was one incident where a flight instructor claimed that outflow from a nearby power plant smoke stack may have contributed to an accident on May 19, 2000 at the Space Coast Regional Airport in Titusville, Florida. The NTSB concluded to the contrary, citing..."*failure of the PIC* *(pilot-in command) to maintain control of the aircraft..."* was the probable cause.

**Note: The aforementioned databases are open to the public and similar search requests may be accessed/queried via the Internet at: http://asrs.arc.nasa.gov and http://www.nasdac.faa.gov.

(2) FAA Regulations, Orders /Notices, and Guidelines

Additionally, the FAA has knowledge of two undocumented instances where pilots of aircraft *intentionally* flew through plumes of an electrical generating power plant and experienced predicable turbulence issues, where intensity varied directly with altitude. Since the pilots were not trained in methods of data collection and the aircraft were not equipped for data collection, no creditable data were collected. Therefore, these intentional incidents were not given further consideration and deemed irrelevant to the analysis.

The team felt it significant to note that the present Notice to Airmen (NOTAM) Temporary Flight Restrictions (TFR), active at the time of the above incidents, should have precluded prudent pilots from flying through or near plumes. Primarily issued for national security reasons, the TFR is listed as follows:

> **FDC 4/0811 FDC ...SPECIAL NOTICE... THIS IS A RESTATEMENT OF A PREVIOUSLY ISSUED ADVISORY NOTICE. IN THE INTEREST OF NATIONAL SECURITY AND TO THE EXTENT PRACTICABLE, PILOTS ARE STRONGLY ADVISED TO AVOID THE AIRSPACE ABOVE, OR IN PROXIMITY TO SUCH SITES AS POWER PLANTS (NUCLEAR, HYDRO-ELECTRIC, OR COAL), DAMS, REFINERIES, INDUSTRIAL COMPLEXES, MILITARY FACILITIES, AND OTHER SIMILAR FACILITIES. PILOTS SHOULD NOT CIRCLE AS TO LOITER IN THE VICINITY OVER THESE TYPES OF FACILITIES.**

The Aeronautical Information Manual (AIM) Chapter 7, addresses Potential Flight Hazards. Section 7-5-1, which discusses the 10 most frequent cause factors for General Aviation that involve the pilot-in-command, include the following:

5. Failure to see and avoid objects or obstructions, and

7. Improper in-flight decisions or planning.

We reviewed this section for information and methods for assessment and mitigation of similar flight hazards within the NAS that are addressed later in this study.

AIM Section 7-5-3 states:

Obstructions To Flight

a. General. Many structures exist that could significantly affect the safety of your flight when operating below 500 feet AGL, and particularly below

200 feet AGL. While 14 CFR Part 91.119 allows flight below 500 AGL when over sparsely populated areas or open water, such operations are very dangerous.

At and below 200 feet AGL there are numerous power lines, antenna towers, etc., that are not marked and lighted as obstructions, and therefore may not be seen in time to avoid a collision. Notices to Airmen (NOTAMs) are issued on those lighted structures experiencing temporary light outages. However, some time may pass before the FAA is notified of these outages, and the NOTAM issued, thus pilot vigilance is imperative.

b. Antenna Towers. Extreme caution should be exercised when flying less than 2,000 feet AGL because of numerous skeletal structures, such as radio and television antenna towers, that exceed 1,000 feet AGL, with some extending higher than 2,000 feet AGL. Most skeletal structures are supported by guy wires that are very difficult to see in good weather and can be invisible at dusk or during periods of reduced visibility. These wires can extend about 1,500 feet horizontally from a structure; therefore, all skeletal structures should be avoided horizontally by at least 2,000 feet. Additionally, new towers may not be depicted in a current aeronautical chart because the information was not received prior to the printing of the chart.

c. Overhead Wires. Overhead transmission and utility lines often span approaches to runways, natural flyways such as lakes, rivers, gorges, and canyons, and cross other landmarks pilots frequently follow such as highways, railroad tracks, etc. As with antenna towers, these high voltage/power lines or the supporting structures of these lines may not always be readily visible and the wires may be virtually impossible to see under certain conditions. In some locations, the supporting structures of overhead transmission lines are equipped with unique sequence flashing white strobe light systems to indicate that there are wires between the structures.

However, many power lines do not require notice to the FAA and, therefore, are not marked and/or lighted. Many of those that do require notice do not exceed 200 feet AGL or meet the Obstruction Standard of 14 CFR Part 77 and, therefore, are not marked and/or lighted. All pilots are cautioned to remain extremely vigilant for these power lines or their supporting structures when following natural flyways or during the approach and landing phase. This is particularly important for seaplane and/or float equipped aircraft when landing on, or departing from, unfamiliar lakes or rivers.

d. Other Objects/Structures. There are other objects or structures that could adversely affect your flight such as construction cranes near an airport, newly constructed buildings, new towers, etc. Many of these structures do not meet charting requirements or may not be charted because of the charting cycle.

Some structures do not require obstruction marking and/or lighting and some may not be marked and lighted even though the FAA recommended it.

Title 14 Code of Federal Regulations (CFR) Part 91 provides the following guidance for minimum safe flight altitudes and defines careless or reckless operation. We mention these two sections, as they will become significant to the scope of our investigation.

These rules apply to all aircraft operated under 14 CFR Parts 91, 121, 135 or 137.

Sec. 91.119

Minimum safe altitudes: General

Except when necessary for takeoff or landing, no person may operate an aircraft below the following altitudes:

(a) *Anywhere.* An altitude allowing, if a power unit fails, an emergency landing without undue hazard to persons or property on the surface.

(b) *Over congested areas.* Over any congested area of a city, town, or settlement, or over any open air assembly of persons, an altitude of 1,000 feet above the highest obstacle within a horizontal radius of 2,000 feet of the aircraft.

(c) *Over other than congested areas.* An altitude of 500 feet above the surface, except over open water or sparsely populated areas. In those cases, the aircraft may not be operated closer than 500 feet to any person, vessel, vehicle, or structure.

(d) *Helicopters.* Helicopters may be operated at less than the minimums prescribed in paragraph (b) or (c) of this section if the operation is conducted without hazard to persons or property on the surface. In addition, each person operating a helicopter shall comply with any routes or altitudes specifically prescribed for helicopters by the Administrator.

Sec. 91.13

Careless or reckless operation.

(a) *Aircraft operations for the purpose of air navigation.* No person may operate an aircraft in a careless or reckless manner as to endanger the life or property of another.

(b) *Aircraft operations other than for the purpose of air navigation.* No person may operate an aircraft, other than for the purpose of air navigation, on any part of the surface of an airport used by aircraft for air commerce (including areas used by those aircraft for receiving or discharging persons or cargo), in a careless or reckless manner as to endanger the life or property of another.

(3) Other Related Material

The Australian Government Civil Aviation Safety Authority (CASA) Advisory Circular (AC) 139-05(0), Guidelines for Conducting Plume Rise Assessments of June 2004, was reviewed as guidance to illustrate a means, but not necessarily the only means of assessing ... *"the potential hazard from plume rise to aircraft operations."* The AC further finds...

- "*Aviation authorities have established that an exhaust plume with a vertical gust in excess of 4.3 meters/second (m/s) may cause damage to an aircraft airframe, or upset an aircraft when flying at low levels.*"
- "CASA requires the proponent of a *facility with an exhaust plume, which has a vertical velocity exceeding the limiting value (4.3 m/s at the aerodrome Obstacle Limitation Surface (OLS) or at 110 meters above the ground level anywhere else) to be assessed for potential hazard to aircraft operation.*"

The FAA does not necessarily approve/disapprove or warrant the data contained in the CASA AC 139-05. The team accepts the information and data contained in AC 139-05 as a valid representation of hazardous exhaust velocities. Lacking other professional data to the contrary, the team used the CASA AC information during the risk assessment and analysis process by stipulating the measures of efflux velocities and altitudes are plausible/representative aviation community data.

However, many narrative sections of AC 139-05 do not apply as Australian laws and regulations regarding land use, hazard assessments, and procedures regarding objects affecting the navigable airspace are far different from those of the United States. A prime example of this is in paragraph 6.2 of the AC where CASA states an obstacle "*...can include the gaseous efflux, which is capable of physical definition or measurement.*" In the United States, 14 CFR Part 77 only considers the height of the structure. For these and similar reasons only quantifiable metrics of plume data will be referenced.

Statement on scope of analysis:

The tools and analysis techniques that were used to analyze the hazards were the "What if" Technique and Preliminary Hazard Analysis (PHA). These tools are described in-depth in the *SMS Manual*. The SRM methodology used by the team to assess and identify safety hazards applied SME knowledge, experience, and expertise across the various disciplines during formal and informal "brainstorming" sessions. The risk analysis team determined the greatest risk of overflight of vertical plumes to aircraft would be in the takeoff and approach/landing phase of flight. Therefore, the analysis would concentrate on these low low-level flying activities (below 1,000 feet AGL). Here, the aircraft would be in close proximity to the ground, and smoke stack/plumes and any resultant turbulence or associated risk would be of greatest consequence.

Therefore, the 4.3 m/s velocity and/or the 110 meters (approximately 360.89 feet) height above the stack CASA criteria for assessment would be most critical during the takeoff/landing phase of flight as the aircraft would be at higher altitudes during other phases, i.e., climb, enroute, and arrival.

The risk analysis team identified the following hazards:

Hazard H1 was identified by association of plumes with other convective activity such as: updrafts, downdrafts, forest fires, and/or weather related activity, and under AIM guidance Obstructions to Flight – Other Objects/Structures.

H1: High efflux temperature or velocity from industrial facilities (power plant exhaust plumes) may cause air disturbances that would have the potential to cause airframe damage and/or negatively affect the stability of aircraft in-flight.

These situations would be most critical at low altitude during the takeoff and/or landing phase when an aircraft is in close proximity to an airport and could possibly result in loss of both aircraft and crew as well as damage to ground facilities.

Hazard H2 was identified by correspondence of concerned citizens and discussion with pilots and ATC personnel.

H2: Exhaust plumes from industrial facilities (power plant, gas or coal fired furnaces, etc.) could result in restricted visibilities with high levels of water vapor, icing, and engine/aircraft contaminants that would have a detrimental effect on aircraft/aircrew performance. These individually or cumulatively could possibly result in substantial aircraft damage, and/or loss of both aircraft and crew as well as damage to ground facilities. These situations would be most critical at low altitude during the takeoff and/or landing phase when an aircraft is in close proximity to an airport.

Section 3 - Risk Analysis and Risk Assessment

Statistical Analysis of Data

In attempting to derive a target level of safety for overflight of exhaust plumes, one difficulty (although most welcome) is that accidents and incidents have been non-existent, so the basis of historical data is limited. The procedure adopted here is to derive target levels of safety for an accident and for a fatal accident due to all causes, and then to estimate what proportion of that risk to allocate to overflight of exhaust plumes. To assess the overall risk, two separate stages are involved as follows:

a) The choice of a unit for the measurement of risk.
b) The choice of a target level for the total risk due to all causes.

A target level of safety for civil aviation may be specified in a number of ways. The most common unit is the fatal accident per departure. In the case of scheduled air carrier operations, the number of departures is recorded annually and the determination of fatal accidents per departure is straightforward. In the case of general aviation, the flights are unscheduled and unrecorded making any estimate of the number of departures extremely inaccurate. However, the FAA conducts an annual survey of general aviation pilots to determine an estimate of the number of hours flown by general aviation pilots during the year in question. Since the survey is scientifically constructed and conducted, the data should be reasonably accurate. Therefore, the decision was made to use incidents per flight hour and fatal accidents per flight hour as the units in the development of the target level of safety.

Table 1 lists the number of accidents, fatal accidents, estimated hours flown, and accident rates for the years 1975 through 2004.

Table 1 - Accidents, Fatalities, Flight Hours, and Rates, 1975 through 2004, U.S. General Aviation

	Accidents		Fatalities			Accidents per 100,000 Flight Hours	
Year	**All**	**Fatal**	**Total**	**Aboard**	**Flight Hours**	**All**	**Fatal**
1975	3995	633	1252	1231	28,799,000	13.87	2.19
1976	4018	658	1216	1203	30,476,000	13.17	2.16
1977	4079	661	1276	1265	31,578,000	12.91	2.09
1978	4216	719	1556	1398	34,887,000	12.08	2.06
1979	3818	631	1221	1203	38,641,000	9.88	1.63
1980	3590	618	1239	1230	36,402,000	9.86	1.69
1981	3500	654	1282	1261	36,803,000	9.51	1.78
1982	3,233	591	1187	1171	29,640,000	10.82	1.96
1983	3,075	555	1,068	1,061	28,673,000	10.67	1.92
1984	3,017	545	1,042	1,021	29,099,000	10.28	1.84
1985	2,739	498	956	945	28,322,000	9.63	1.74
1986	2,581	474	967	879	27,073,000	9.49	1.73
1987	2,495	446	837	822	26,972,000	9.18	1.63
1988	2,388	460	797	792	27,446,000	8.65	1.66
1989	2,242	432	769	766	27,920,000	7.97	1.52
1990	2,242	444	770	765	28,510,000	7.85	1.55
1991	2,197	439	800	786	27,678,000	7.91	1.57
1992	2,111	451	867	865	24,780,000	8.51	1.82
1993	2,064	401	744	740	22,796,000	9.03	1.74
1994	2,022	404	730	723	22,235,000	9.08	1.81
1995	2,056	413	735	728	24,906,000	8.21	1.63
1996	1,908	361	636	619	24,881,000	7.65	1.45
1997	1,844	350	631	625	25,591,000	7.19	1.36
1998	1,905	365	625	619	25,518,000	7.44	1.41
1999	1,905	340	619	615	29,246,000	6.5	1.16
2000	1,837	345	596	585	27,838,000	6.57	1.21
2001	1,727	325	562	558	25,431,000	6.78	1.27
2002	1,715	345	581	575	25,545,000	6.69	1.33
2003	1,741	352	632	629	25,705,000	6.77	1.37
2004	1,614	312	556	556	25,900,000	6.22	1.2
Totals	77,874	14,222	26,749	26,236	849,291,000		
Means	2595.8	474.0667	891.6333	874.5333	28,309,700	9.012333	1.649333

From Table 1, we see that the accident rate trend has been downward. This is illustrated in Figure 1.

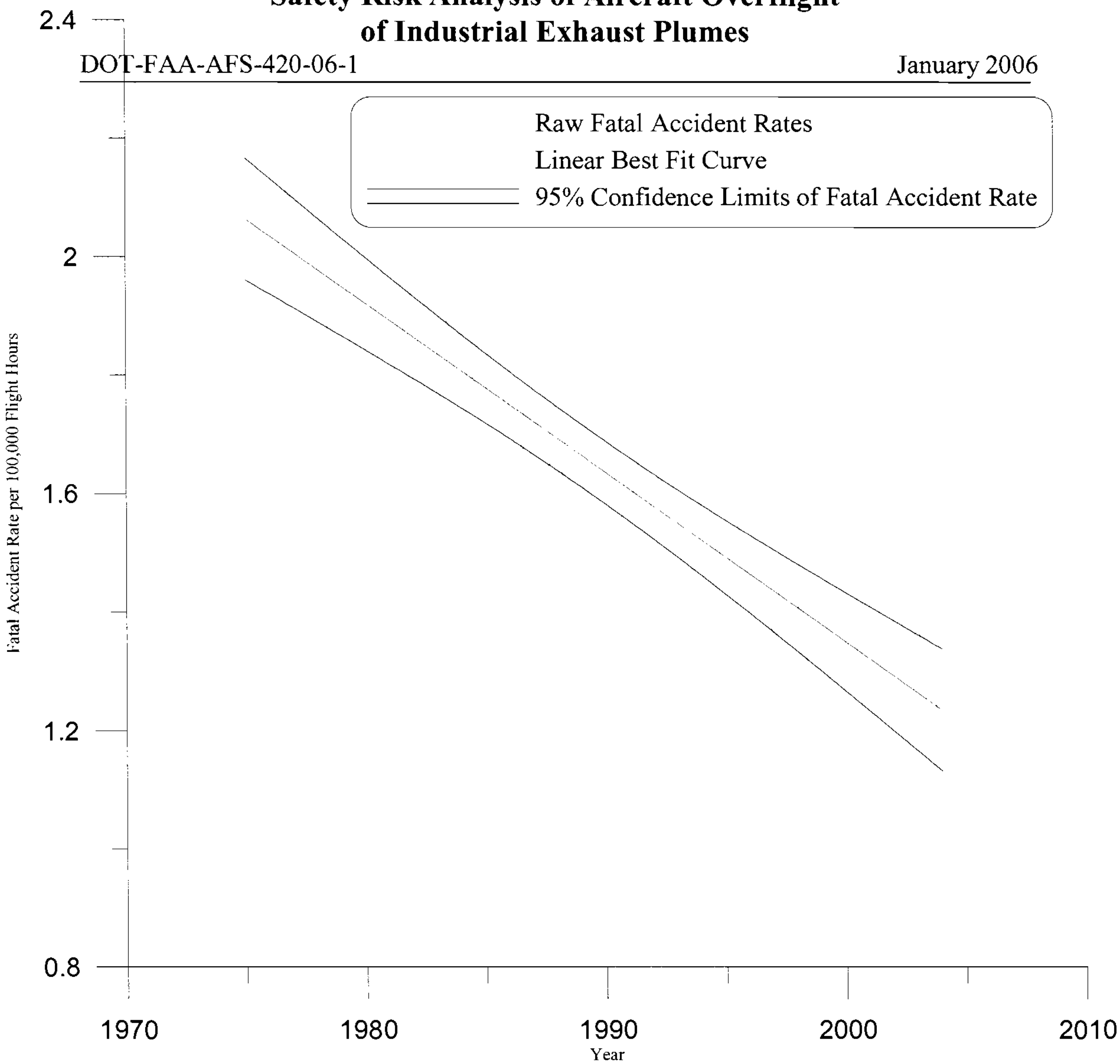

Figure 1. U.S. General Aviation Fatal Accident Rates (all causes) in Fatal Accidents per 100,000 Hours.

The confidence bands depicted in Figure 1 give an indication of the range of values the actual accident rate may fall within with a probability of 0.95. The lower confidence band in Figure 1 intersects the year 2005 at about 1.0. This indicates that a conservative estimate of the current fatal accident rate is 1 in 100,000 hours or 1×10^{-5} per flight hour.

Since the fatal accident rate is lower than the overall accident rate, we may conservatively choose 1×10^{-5} per flight hour as the overall target level of safety for flights of general aviation aircraft. An overflight of an exhaust plume is just one of many factors that could cause an accident or incident. When the number of factors that could cause a failure or accident is essentially unknown, standard engineering practice is applied.

Standard engineering practice assumes there are 100 possible causes and apportions the probability equally between the assumed factors. Therefore, since the overall target level of safety is 1×10^{-5} per flight hour, the target level of safety for overflight of an exhaust plume would be $1 \times 10^{-5}/ 10^{2} = 1 \times 10^{-7}$ per flight hour.

From Table 1 we see that there were approximately 849,291,000 flight hours by general aviation aircraft during the time period 1975 to 2004. During this time period a careful search of the available aviation databases revealed that zero accidents or incidents related to overflight of a plume have been reported. This implies that the probability of an accident or incident caused by overflight of a plume is very small. If there were just one reported accident or incident, the estimated rate would be 1/849,241,000 or 1.2×10^{-9}. If there were two reported accidents or incidents, the estimated rate would be 2/849,241,000 or 2.4×10^{-9}. Therefore, it is safe to conclude that the accident/incident rate for overflights of exhaust plumes is of the order of 10^{-9} or less. Since the target level of safety was determined to be 1×10^{-7}, the probability of an accident or incident from overflight of an exhaust plume is less than the target level of safety. Since the target level of safety is met, the likelihood of an accident or incident caused by overflight of an exhaust plume is acceptably small.

Human Factors Assessment

Power plant exhaust plumes do not present an immediate or critical increase in human mental or physical workload, resulting in any commensurate decrease in performance. However, like any phenomenon in the NAS, pilots need to be properly armed with the knowledge that it exists. This prior knowledge allows for proper flight planning of routes and avoidance strategies, thus eliminating inadvertent visual or physical contact with a plume. As in any operation in the NAS, pilot comfort levels directly impact anxiety that subsequently may cause an increase in self-induced levels of stress and mental/physical workload. The more knowledge pilots have access to regarding any respective flight, the more comfortable he/she is. It is strongly advised that the existence of plumes in a flying area be published and disseminated to pilots for the reasons mentioned above. Pilots should be prepared to see and avoid power plant exhaust plumes just as they would be prepared to see and avoid any obstacle in their flight path, expected or unexpected. We would expect that any plume encounter would be a relatively benign event. The pilot's mental and/or physical resources would not be so task-overloaded as to preclude a safe maneuver out of, and away from the condition.

Preliminary Risk Assessment

A preliminary risk assessment of the two identified hazards was completed during brainstorming sessions by the technical team consisting of the previously mentioned FAA SME. The risk associated with a hazard is the composite of predicted severity (Table 2) and likelihood (Table 3) of the potential effect or outcome of the hazard in the worst credible system state. The following SMS Manual matrixes were used to develop the risk matrix for overflight of vertical plumes. The "Flying Public" row of the "Effect On" column was utilized for Severity and the "Qualitative ATC Service/NAS Level System" column was used for Likelihood.

Table 2 - Severity definitions

[redacted]	**Hazard Severity Classification**				
	No Safety Effect **5**	**Minor** **4**	**Major** **3**	**Hazardous** **2**	**Catastrophic** **1**
	Slight increase in ATC workload	Slight reduction in ATC capability or significant increase in ATC workload	Reduction in separation as defined by a low/moderate severity operational error (as defined in FAA Order 7210.56) or significant reduction in ATC capability	Reduction in separation as defined by a high severity operational error (as defined in FAA Order 7210.56) or a total loss of ATC Capability (ATC Zero)	Collision with other aircraft, obstacles or terrain
	- No effect on flight crew - Has no effect on safety - Inconvenience	- Slight increase in flight crew workload - Slight reduction in safety margin or functional capabilities - Physical discomfort of occupants	- Significant increase in flight crew workload - Significant reduction in safety margin or functional capability - Physical distress possibly including injuries	- Large reduction in safety margin or functional capabilities - Serious or fatal injury to small number of occupants or cabin crew - Physical distress/ excessive workload	Outcome would result in: - Hull loss - Multiple fatalities

Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes

DOT-FAA-AFS-420-06-1 January 2006

Table 3 - Likelihood Definitions

	NAS System			**Flight Procedures**	**Operational**	
	Quantitative[1]	**Qualitative**				
		Individual Item/System	**ATC Service/ NAS Level System**[2]		**Per Facility**[3]	**NAS-wide**[4]
Frequent A	Probability of occurrence per operation/operational hour is equal to or greater than $1x10^{-3}$	Expected to occur frequently for an item	Continuously experienced in the system	Probability of occurrence per operation/ operational hour is equal to or greater than $1x10^{-5}$	Expected to occur more than once per week	Expected to occur every 1-2 days
Probable B	Probability of occurrence per operation/operational hour is less than $1x10^{-3}$, but equal to or greater than $1x10^{-5}$	Expected to occur several times in the life of an item	Expected to occur frequently in the system		Expected to occur about once every month	Expected to occur several times per month
Remote C	Probability of occurrence per operation/operational hour is less than $1x10^{-5}$ but equal to or greater than $1x10^{-7}$	Expected to occur sometime in the life cycle of an item	Expected to occur several times in system life cycle	Probability of occurrence per operation/ operational hour is less than $1x10^{-5}$ but equal to or greater than $1x10^{-7}$	Expected to occur about once every 1 10 years	Expected to occur about -once every few months
Extremely Remote D	Probability of occurrence per operation/operational hour is less than $1x10^{-7}$ but equal to or greater than $1x10^{-9}$	Unlikely but possible to occur in an item's life cycle	Unlikely but can reasonably be expected to occur in the system life cycle	Probability of occurrence per operation/ operational hour is less than $1x10^{-7}$ but equal to or greater than $1x10^{-9}$	Expected to occur about once every 10-100 years	Expected to occur about once every 3 years
Extremely Improbable E	Probability of occurrence per operation/operational hour is less than $1x10^{-9}$	So unlikely, it can be assumed that it will not occur in an item's life cycle	Unlikely to occur, but possible in system life cycle	Probability of occurrence per operation/ operational hour is less than $1x10^{-9}$	Expected to occur less than once every 100 years	Expected to occur less than once every 30 years

Preliminary Risk

Figure 2 reflects the definition of risk being the composite of severity and likelihood. This matrix classifies risk into three levels: High, Medium, and Low. The risk levels used in the matrix are defined as:

- **High risk** – unacceptable risk.

- **Medium risk** – acceptable risk; minimum acceptable safety objective; proposal may be implemented, but tracking and management are required.
- **Low risk** – acceptable without restriction or limitation; hazards are not required to be actively managed, but are to be documented.

The safety risk team preliminary risk assessment matrix in Figure 2 indicates where the initial hazards (H1/H2) identified by overflight of vertical plumes (in the takeoff/landing phase 1,000 feet AGL and below) would be situated on the risk matrix without considering or implementing any of the mitigations previously discussed. The team performed their analysis of the predictive risks associated with the plumes and determined the effects of both H1 and H2 hazards as low, or in the green section of the risk matrix. As a result of this assessment, the risk associated with plumes is deemed acceptable without restriction, limitation, or further mitigation.

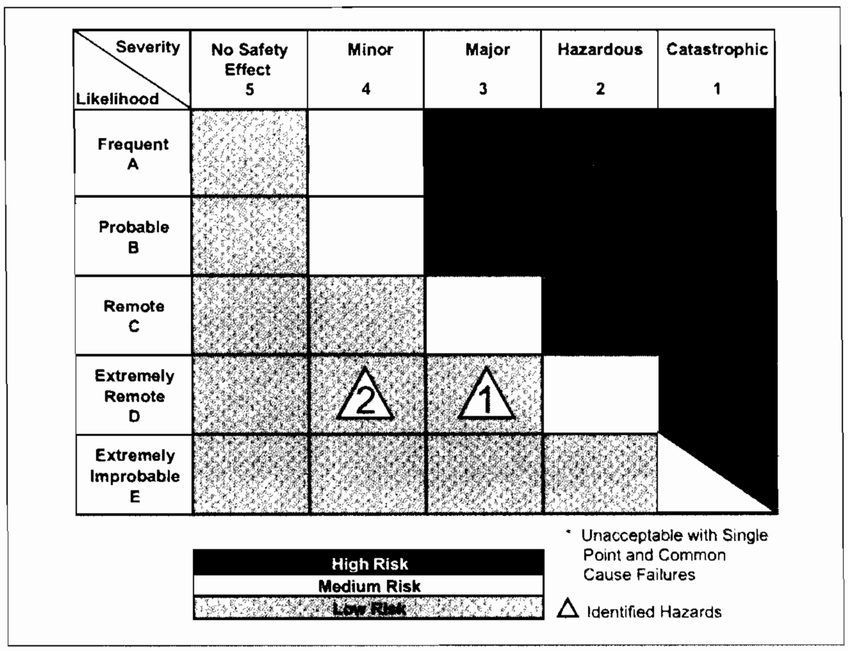

Figure 2 – Preliminary Risk Matrix Without Mitigation (current Risk)

<u>Section 4</u> - Summary of Risk Analysis Team Deliberations

The review of the material in Section 2, the statistical analysis of data and the in-depth professional discussion, experience, and knowledge of SMEs on the team, led to the following preliminary observations:

- Given the virtually non-existent accident/incident safety data by either GA or commercial aviation pilots, the team was extremely confident in drawing the preliminary inference that hazard(s) associated with plume overflight represent an extremely low risk to aviation and the flying public.
- However, and in light of supporting data to the contrary, the team agreed that intentional and/or inadvertent overflight of industrial plumes at low altitudes (less than 1,000 feet above) during high velocity operation of the facility could possibly result in aircraft upset and a resultant incident or accident.
- The team determined that low, close-in operations at small to medium size airports by general aviation (GA) aircraft, particularly aircraft under 12,500 lbs. and those in the Light Sport Aircraft (LSA) category, would be of greatest potential concern.
- The SME team considered and discussed their belief that safety data which indicated few, if any accidents/incidents attributable to the issue may be a reflection of the cumulative actions over many years of prudent aviators and ATC personnel. This includes knowledge of and training in established "see-and avoid" techniques and/or mitigating operational procedures. The situation with plumes was deemed similar to many hazards present in the NAS today (see AIM Chapter 7 for further examples). Moreover, rules and regulations restricting the altitude for overflight of power plant facilities coupled with pilot training, alerting, and the common sense aviator aptitude were determined to be the major factors in the scarcity of associated data and resultant low risk factor.
- At airports where power plants could not be optimally avoided by current approach procedures or when weather resulted in plume footprints that could adversely affect airport operations, ATC past and present operational procedures were deemed more than adequate to maintain established acceptable levels of risk.
- Plume effects (H2) on aircraft, engine component function, and/or corrosion were deemed inconsequential by the SME team.
- The team noted the CASA flight restriction of 4.3m/s above OLS or 110 (meters) AGL as less restrictive than the 14 CFR Part 91 restrictions previously mentioned.

Section 5 – Conclusions, Recommendations, and Residual Risk

Safety is freedom from unacceptable risk. Everyday in the NAS aircraft and airmen operate with hazards that constantly present various levels of risk. From bird strikes, to engine failures, to runway incursions, these situations present vastly different scenarios for the pilot, crew, and ATC personnel to consider. However, these hazards all have one characteristic in common – they represent ***acceptable risk*** that is considered and mitigated as necessary to allow flight operations to proceed to a safe conclusion in the vast majority of cases.

Many of these risks represent far greater concern and thereby require a more complicated Risk Control Strategy or mitigation effort than the issue addressed by this study.

Our interpretation of available data is not so much that plumes are not hazards or present zero risk, but that pilots and controllers operating within the NAS have been and will continue to apply prudence and common sense skills to constantly "see and avoid" any potential hazard. These mitigating techniques are employed everyday throughout NAS through timely communication, training, and procedures for operating near hazardous weather, forest fires, large sporting events, volcanic ash, migratory bird activity, antenna towers, and overhead wires.

The risk assessment team offers the following conclusions and recommendations with regard to "overflight of plumes" and associated hazards:

Conclusions:

1. Given the considerably large pool of safety data available, it is safe to conclude that the accident/incident rate for overflights of exhaust plumes is of the order of 1×10^{-9} or less. Since the target level of safety was determined to be 1×10^{-7}, the probability of an accident or incident from overflight of an exhaust plume is less than the target level of safety. Since the target level of safety is met, the current likelihood of an accident or incident caused by an overflight of an exhaust plume is acceptably small.

2. Current regulations and advisories as well as the present Notice to Airmen (NOTAM) Temporary Flight Restrictions should preclude prudent pilots from flying through or near plumes, thereby making the aviation risk essentially zero.

3. Safety data and TLS notwithstanding, the FAA believes that flight over or around plume generating facilities should be avoided as there is the *potential* (however low) for aircraft upset at close proximity to high velocity plumes.

Recommendations:

Given the extremely low risk these plumes present, further mitigation is not required. However, the risk assessment team would offer that the FAA continue to enhance awareness programs that have been successful with similar hazards of acceptable risk levels. These programs include pilot and ATC personnel professional education, communication, advisement and avoidance strategies, and operational techniques. Accordingly, the safety risk assessment team recommends the FAA:

(a) Amend the Aeronautical Information Manual (AIM) Chapter 7, Section 5 with wording to the effect that overflight at less than 1,000 feet vertically of plume generating industrial sites should be avoided.

(b) Publish (as appropriate) the position and nature of the present power plants located near public airports in the Airport/Facility Directory (A/FD), and issue a Notice to Airmen (NOTAM) when operationally necessary.

(c) Make the Temporary Flight Restriction (TFR) that includes the overflight of power plants (which was issued primarily for national security purposes) - a permanent flight restriction where operationally feasible.

(d) Amend FAA Order 7400.2 to consider a plume generating facility as a hazard to navigation when expected flight paths pass less than 1,000 feet above the top of the object.

(e) Advisory Circular 70/7460-2K Proposed Construction of Objects That May Affect the Navigable Airspace - Change Instructions for Completing FAA Form 7460-1 – Notice of Proposed Construction or Alteration, Item # 21, to add:

> "For structures such as power plants or any industrial facility where exhaust plume discharge could reasonably be expected and reportable under the provisions of Part 77, thoroughly explain nature of the discharge."
>
> Amend the AC as necessary to explain this change.

Residual Risk

A risk matrix, as shown in Figure 3, indicates where the residual risk of the hazards identified with the overflight of vertical plumes are situated with the implementation of the recommendations described above.

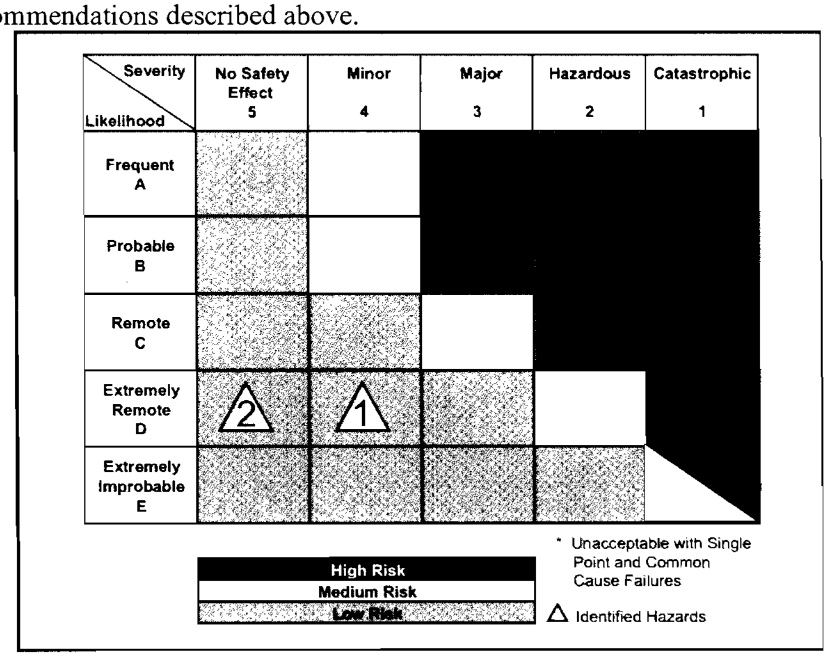

Figure 3 – Risk Matrix with Mitigation* (Residual Risk)

* Not required

Glossary of Terms

Aviation Safety Reporting System (ASRS) and Aviation Safety Reporting Program (ASRP). ASRS and ASRP are voluntary programs designed to encourage the identification and reporting of deficiencies and discrepancies in the airspace system. The National Aeronautics and Space Administration (NASA) accomplishes receipt, processing, and analysis of raw data rather than the FAA, which ensures the anonymity of the reporter and of all parties involved in a reported occurrence or incident and, consequently, increase the flow of information necessary for the effective evaluation of the safety and efficiency of the system. [Advisory Circular 00-46, *Aviation Safety Reporting Program]*

Accident. An event associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and until all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage.

Accident/Incident Reporting Data System (AIDS). The FAA AIDS database contains accident and incident data records for all categories of civil aviation.

Assessment. An estimation of the size/scope of risk or quality of a system or procedure.

Effect. The effect is a description of the potential outcome or harm of the hazard if it occurs in the defined system state.

14 CFR Part 91 (General Aviation). Prescribes the operation of aircraft (other than moored balloons, manned rockets, and unmanned free balloons, which are governed by CFR Part 101, and ultralight vehicles operated in accordance with CFR Part 103) within the United States, including the waters within three nautical miles of the U.S. coast. Flights operating for recreation and training are generally carried out under CFR Part 91. Although general aviation usually involves small aircraft, the definition depends on the nature of the operation rather than the size of the aircraft.

14 CFR Part 121 (Air Carrier). Refers to scheduled domestic airlines and cargo carriers that fly large transport category aircraft.

14 CFR Part 135 (Air Taxi and Commuter). Refers to either scheduled (commuter operations) or nonscheduled (air taxi operations) flights. Scheduled CFR Part 135 operations apply to smaller aircraft carrying nine or fewer passengers on regularly scheduled routes. Nonscheduled CFR Part 135 operations apply to smaller aircraft carrying nine or fewer passengers with schedules that are arranged between the passengers and the operator. The nonscheduled operations also include cargo planes with payload capacities of 7,500 pounds or less.

14 CFR Part 137 (Agricultural). Refers to agricultural aircraft operations. Agricultural aircraft operation means the operation of an aircraft for the purpose of (1) dispensing any economic poison; (2) dispensing any other substance intended for plant nourishment, soil treatment, propagation of plant life, or pest control; or (3) engaging in dispensing activities directly affecting agricultural, horticultural, or forest preservation, but not including the dispensing of live insects.

Fatal Injury. The NTSB defines a fatal injury as any event that results in death within 30 days of the event.

Hazard. Any real or potential condition that can result in injury, illness, or death to people; damage to, or loss of a system (hardware or software), equipment or property; and/or damage to the operating environment. A hazard is a prerequisite to an accident or incident.

Hazard Tracking. Hazard tracking is a closed-loop means of ensuring that the requirements and mitigations associated with each hazard that has associated medium and/or high risk are implemented. Hazard tracking is the process of defining safety requirements, verifying implementation, and reassessing the risk to make sure the hazard meets its risk level requirement before being accepted.

Incident. The NTSB defines an incident as an event, other than an accident, associated with the operation of an aircraft that affects or could affect the safety of operations.

Likelihood. Likelihood is an expression of how often an event is expected to occur. Severity must be considered in the determination of likelihood. Likelihood is determined by how often the resulting harm can be expected to occur at the worst credible severity, which will usually occur in the worst credible system state.

Mitigation. An action taken to reduce the risk of a hazard.

National Airspace System (NAS). An integrated set of constituent pieces that are combined in an operational or support environment to accomplish a defined objective. These pieces include people, operational environment, usage, equipment, information, procedures, facilities, services, and other support services.

National Aviation Safety Data Analysis Center (NASDAC). The NASDAC system enables users to perform queries across multiple databases and display queries in useful formats. The NASDAC is a data warehouse and integrated database system.

Plume. Thermal updrafts generally associated with exhaust from the smoke stacks of power generating facilities, industrial production facilities, or other systems, which could have the ability to release large amounts of pressurized or otherwise unstable air. Can be visible or invisible in the air and disperse at various velocities/rates and directions for a given facility output and atmospheric conditions.

Preliminary Hazard Analysis (PHA). A risk analysis tool used in the hazard identification process for nearly all risk management applications except the most time-critical.

The broad scope of this tool provides a guide to the identification of issues. The PHA considers all of the hazards inherent to each aspect of an operation, without regard to risk. The PHA helps overcome the tendency to focus immediately on risk in one aspect of an operation, sometimes at the expense of overlooking more serious issues elsewhere in the operation.

Process. An organized group of related activities that work together to produce a desirable condition.

Qualitative Data. Subjective data is expressed as a measure of quality; nominal data.

Quantitative Data. Objective data expressed as a quantity, number or amount that allows for more rational analysis and substantiation of findings.

Risk. The risk associated with a hazard is the composite of predicted severity and likelihood of the potential effect or outcome of the hazard in the worst credible system state. The two types of risk addressed in this study are, (1) current, (2) residual:

> **Current.** Current risk is the predicted severity and likelihood of an effect associated with a hazard at the current time.
>
> **Residual.** Residual risk is the remaining risk that exists after all control/mitigating techniques have been implemented or exhausted.

Risk Assumption Strategy. To accept the likelihood, probability, and consequences associated with the risk.

Risk Avoidance Strategy. To select a different approach or to not participate in the operation, procedure, or system development to avert the potential of occurrence and/or consequence.

Risk Control Strategy. To develop options and alternatives and/or take actions to minimize or eliminate the risk.

Safety. Freedom from unacceptable risk.

Safety Management System (SMS). An integrated collection of processes, procedures, policies, and programs that are used to assess, define, and manage the safety risk in the provision of air traffic control (ATC) and navigation services.

Safety Risk Management (SRM). A formalized, proactive approach to system safety. SRM is a methodology usually applied to all (NAS) changes that ensures all risks are identified and mitigated prior to the change being made. For the purposes of this study, SRM provides a flexible "closed-loop" safety analysis framework well-suited to the analysis of presumed hazards.

Severity. Severity is the measure of how bad the results of an event are predicted to be. Severity is determined by the worst credible potential outcome.

Substantial Damage – The NTSB defines substantial damage as failure that adversely affects the structural strength, performance, or flight characteristics of the aircraft, and would normally require major repair or replacement of the affected component. Engine failure or damage limited to the engine if only one engine fails or is damaged, bent fairings or cowlings, dented skin, small puncture holes in the skin or fabric, ground damage to rotor or propeller blades, and damage to landing gear, wheels, tires, engine accessories, brakes, or wingtips are not considered "substantial damage."

Target Level of Safety (TLS). The target level of safety is the maximum allowable probability of a hazardous event. The target level of safety is usually determined from historical data for various operations, but is sometimes developed through analysis.

"What - if" Technique. Is a brainstorming method designed to add discipline and structure to the experiential and intuitive expertise of operational personnel.

Worst Credible System State. In this definition, "*worst*" is the most unfavorable conditions expected (e.g., extremely high levels of efflux material and velocity, extreme weather disruption, etc.); "*credible*" implies that it is reasonable to expect the assumed combination of extreme conditions will occur within the NAS.

Appendix A – Risk Assessment Team Members

Name	Organization/Position
Alan Jones	AFS-420/Operations Research Analyst
Dr. James Yates	AFS-420/FAA Contractor-ISI, Senior Engineer & Pilot
Dean Alexander	AFS-440/ Test Director & Airspace System Inspection Pilot
Rick Dunham	AFS-440/ Test Director & Airspace System Inspection Pilot
Lt. Col Paul McCarver	AFS-420/USAF Pilot & Military Liaison
Michael Werner	AFS-420/Pilot & Aviation Safety Inspector (Operations)
Gary Powell	AFS-420/Pilot & Aviation Safety Inspector (Operations)
Larry Ramirez	AFS-440/Air Traffic Control Liaison
James Nixon	AFS-420/FAA Contractor-ISI, Pilot & Approach Procedure Specialist
Mark Reisweber	AFS-440/Engineering Psychologist (Human Factors) & Pilot
John Holman	AFS-420/FAA Contractor-ISI, Pilot & Approach Procedure Specialist

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January 2006