TECHNICAL REPORTS ON CHAFF AND FLARES

TECHNICAL REPORT NO. 1 — REVIEW OF AVAILABLE DATA

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EXECUTIVE SUMMARY

This Technical Report culminates the first phase of a study being conducted by the U.S. Air Force, Headquarters Air Combat Command (ACC) on the environmental effects of using chaff and self-protection flares in military aircraft training. (Illumination flares are not included in this study.) The objectives of the first phase of the study were to:

- Identify environmental, health, and safety issues associated with chaff and flares use.
- Compile and analyze data on the materials used in the manufacture of chaff and flares and their deployment components.
- Collect information on how chaff and flares are used in aircraft training.
- Review regulatory and policy issues related to chaff and flares use.
- Review available data, literature, and studies pertaining to chaff and flares and their impacts on the environment.
- Identify further data needs and research efforts for resolving outstanding issues.

The information contained in this report addresses potential effects from chaff and flares use on human health and safety, air quality, physical resources (soil and water), biological resources, land use and visual resources, and cultural resources. Issues related to fires from flare use are also addressed. In addition, this report describes regulatory and policy considerations that may affect the use of chaff and flares and discusses their implications for training activities.

In general, existing studies on chaff and flares are scarce and inconclusive. Some conclusions can be derived from an analysis of the composition of chaff and flares and how they are used in training. Other issues require more research before a definitive conclusion can be reached. The following paragraphs summarize the findings of this report and identify areas of additional research recommended for future study.

Effects of Chaff Use

Findings

The materials in chaff are generally nontoxic except in quantities significantly larger than those any human or animal could reasonably be exposed to from chaff use. Safety risks were found to be extremely low and isolated to specific circumstances that can be avoided or managed. The primary risk is interference with air traffic control radar. Air quality issues include questions about the potential for chaff to break down into respirable particle sizes and the remote possibility that some hazardous air pollutants may be generated from older chaff or from pyrotechnic impulse cartridges historically used with some chaff models.

The potential for chaff to affect soil and water has not been conclusively studied, but impacts are unlikely. Levels of use and accumulation would have to be extremely high to generate any significant adverse effects. More research is needed in this area to verify these conclusions. In particular, nothing is known about the behavior of chaff in anaerobic conditions, such as found in swamps.

No adverse impacts on biological resources have been identified, but a few unresolved issues remain. Since chaff is generally nontoxic, toxicity-related impacts on wildlife are not anticipated. Few animals are expected to suffer physical effects from chaff ingestion, but some questions remain about surface feeding waterfowl and, possibly, small mammals. Effects from inhalation are not considered a significant issue, since chaff particles would represent a small percentage of the particulates regularly inhaled by animals. Given the properties of chaff fibers, skin irritation is not expected to be a problem, except in cases where chaff may be used by birds or small mammals as nesting material. This issue needs further investigation.

Impacts on land use and visual resources are directly related to levels of accumulation. The primary concern is with the incidental debris associated with chaff deployments (packaging, plastic components, etc.) more than with the chaff fibers themselves. Use of chaff over or immediately adjacent to highly sensitive areas such as Wilderness Areas, Wild and Scenic Rivers, National Parks and Monuments, and other pristine natural areas may be incompatible with the land use and visual resource management objectives for those areas. Issues regarding potential effects on cultural resources are also primarily related to accumulation and aesthetics, or, in the case of Native American resources, are indirectly associated with effects on physical and biological resources. While nothing is known about the potential for chemical effects from chaff on archaeological or architectural resources, they are considered to be remote.

Recommendations

Although the risks of significant problems appear low, based on the data collected to date, there are a few issues that may have a potential for adverse impacts which could be avoided by adopting some restrictions or limitations on chaff use. Recommended mitigation measures include:

- Restricting chaff training to designated special use airspace to avoid potential for interference with air traffic control radar, or, alternatively, confining use of chaff to types that have the interfering dipoles removed.

- Suspending use of chaff with lead and with impulse cartridges that contain chromium compounds.

- Avoiding use of chaff over and near primitive and other highly sensitive land use and visual resource areas.

If these mitigation measures cannot be adopted without adversely affecting Air Force training, further study will be required to better define the risks to health, safety, and environmental resources.

Effects of Flares Use

Findings

Toxicity is not expected to be a concern with flares, since the primary material in flares, magnesium, is not highly toxic; the magnesium is combined with a Teflon binder, rendering the flares relatively inert, and it is highly unlikely that humans or animals would ingest flare material. The main issue with flares is their potential to start fires that can spread and have significant adverse impacts on the environment. Fires can cause a wide variety of significant secondary effects on soil, water resources, biological resources, land use, visual resources, and cultural resources.

The hazard risk associated with flare-induced fires depends on a number of factors, including the probability of a burning flare reaching the ground (or a flare igniting after reaching the ground), the probability of the burning flare igniting other materials on the ground, and the probability of a fire spreading and causing significant damage. The frequency of burning flares landing on the ground is not information collected in mishap databases, and calculating a probability would involve too many unknown variables to be accurate. However, given that this occurs, methodologies exist for predicting the risk that it will start a fire and that the fire will spread. Using a combination of computer modeling and input databases with information on meteorological conditions and the flammability of various types of vegetation, the relative risk of wildfires can be predicted. However, this analysis can only be conducted on a site-specific basis because conditions vary so widely from location to location.

Other concerns include risks of injury from dud flares, which can be severe but have a low probability of occurrence. There is also some concern that dud flares qualify as a hazardous waste. Initiator cartridges used with some flares still contain chromium and, in some cases lead, which are hazardous air pollutants under the Clean Air Act. Potential impacts on biological resources are primarily related to fire, but there is some concern that burning flares might impair the vision of some animals. Although litter from flare debris is less than with chaff use, it may be a concern in certain pristine areas.

Recommendations

Based on the findings to date, recommended mitigation measures for flares include:

- Avoiding use of flares at low altitudes over areas sensitive to fire hazards during high-risk periods.

- Establishing a capability to analyze fire risks on a site-specific basis.

- Replacing initiator cartridges on flares with models that do not contain toxic air pollutants such as chromium and lead.

- Avoiding use of flares over and near residential areas, high-use recreation areas, and sensitive land use and visual resource areas.

If any of these measures are incompatible with Air Force training requirements, further study will be required to quantify the resulting risks.

Future Activities

As a result of the first phase data collection and analysis, a number of follow-on research activities are recommended, including the following:

- A field study at two high-use locations to determine whether there are any observable effects from past use of chaff and flares. The field study will examine a range of issues, including experience with flare-induced fires and their environmental effects and effects of accumulated chaff on soil and water chemistry, biological resources, and aesthetics. Soil and water samples will be collected and analyzed.

- A series of laboratory tests analyzing the behavior over time of chaff and flares in water, soil, and other media.

- Chaff dispersion modeling to further understand effects on air quality and other environmental resources.

- Verification of risk probabilities for system safety issues and estimation of probabilities for hazards that remain a credible concern.

- Contacts with other (outside the Department of Defense) federal and state agencies to identify their concerns and obtain any information they have on impacts from chaff and flares use.

Finally, public concerns about chaff and flares may be based more on perceived problems than actual problems, especially if there is little factual data on actual risks and impacts. Consideration might be given to preparing a brochure on chaff and flares and their effects for public distribution in areas used or proposed to be used for training with these countermeasures.

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ACRONYMS AND ABBREVIATIONS

AAA	anti-aircraft artillery
ACC	Air Combat Command
ACGIH	American Conference of Governmental Industrial Hygienists
ACT	Air Combat Tactics
AFB	Air Force Base
AFM	Air Force Manual
AFR	Air Force Regulation
AGL	above ground level
AIRFA	American Indian Religious Freedom Act
ALDS	Automatic Lightning Detection System
ARPA	Archaeological Resources Protection Act
ATM	Air Traffic Management
BLM	Bureau of Land Management
CAA	Clean Air Act
CATEX	Categorical Exclusion
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DEIS	Draft Environmental Impact Statement
DIALOG	Dialog Information Retrieval Service
DOD	Department of Defense
DOI	Department of the Interior
DROLS	Defense Research On-Line System
DTIC	Defense Technical Information Center
EA	Environmental Assessment
EC	electronic combat
ECM	electronic countermeasures
EIAP	Environmental Impact Analysis Process
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
F	Fahrenheit
FAA	Federal Aviation Administration
FEIS	Final Environmental Impact Statement
FIE	Fighter Intercept Exercises
FLPMA	Federal Land Policy and Management Act
FOD	Foreign Object Damage
FONSI	Finding of No Significant Impact
FTCA	Federal Tort Claims Act
HMDB	Hazardous Materials Data Bank
HRI	Hazard Risk Index

HSDB	Hazardous Substances Data Bank
IAMS	Initial Attack Management System
IFSL	Intermountain Fire Sciences Laboratory
IR	infrared
IRIS	Integrated Risk Information System
LD	lethal dose
MACT	Maximum Achievable Control Technology
MCA	Military Claims Act
MPRSA	Marine Protection, Research, and Sanctuaries Act
MOA	Military Operations Area
MSL	mean sea level
MTR	Military Training Route
NAAQS	National Ambient Air Quality Standards
NAGPRA	Native American Graves Protection and Repatriation Act
NAS	Naval Air Station
NEPA	National Environmental Policy Act
NFDRS	National Fire Danger Rating System
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NOTAM	Notice to Airmen
NPS	National Park Service
NTIS	National Technical Information Service
OHM/TDS	Oil and Hazardous Materials/Technical Assistance Data System
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
P.L.	public law
PRA	Probably Risk Assessment
PSD	Prevention of Significant Deterioration
RAWS	Remote Automatic Weather Stations
RCRA	Resource Conservation Recovery Act
ROD	Record of Decision
RTEC	Registry of Toxic Effects of Chemical Substances
SAC	Strategic Air Command
SACR	Strategic Air Command Regulation
SAM	surface-to-air missile
SAR	Safety Analysis Review
SEA	Science and Engineering Associates, Inc.
SIP	State Implementation Plan
TAC	Tactical Air Command
TACR	Tactical Air Command Regulation
TCTO	Time Compliance Technical Order
TDY	temporary duty
TOMES	Toxicological, Occupational Medicine, Environmental Series
TWS	tail warning system
UKHSEMD	United Kingdom Health and Safety Executive for the Ministry of Defense

USAF	United States Air Force
USC	United States Code
USDA	United States Department of Agriculture
USDI	United States Department of the Interior (also DOI)
UTTR	Utah Test and Training Range
WAPA	Western Area Power Administration

1.0 INTRODUCTION

1.1 SCOPE AND OBJECTIVES OF STUDY

The United States Air Force, Headquarters Air Combat Command (ACC) has initiated a study to develop more comprehensive scientific data on the employment of chaff and flares in training and the associated environmental impacts. These data are needed to perform future environmental analysis prior to releasing chaff and flares in military training ranges, along Military Training Routes (MTRs), and in Military Operations Areas (MOAs) and to address public concerns and misconceptions about their impacts. This study will result in the preparation of a set of Technical Reports that identify the environmental impacts and health risks associated with the dispensing of chaff and flares from aircraft. These reports will be used as source documents for future environmental impact analyses.

Chaff and flares are defensive mechanisms employed from military aircraft to avoid detection and/or attack by adversary air defense systems. Chaff consists of small fibers that reflect radar signals and, when dispensed in large quantities from aircraft, form a cloud that temporarily hides the aircraft from radar detection. Flares are high-temperature heat sources ejected from aircraft that mislead heat-sensitive or heat-seeking targeting systems and decoy them away from the aircraft. The scope of this study is limited to "self-protection" flares, employed to keep aircraft from being targeted; illumination flares used to provide light at night will not be addressed by this study. Chaff and flares are used in combat to keep aircraft from being targeted by weapons such as surface-to-air missiles (SAMs), anti-aircraft artillery (AAA), and other aircraft.

The scope of the topics being addressed through this study comprises the range of resources typically analyzed in Environmental Assessments (EAs) and Environmental Impact Statements (EISs), including air quality, land and water resources, biological resources, land use and aesthetics, and cultural resources, along with related regulatory and policy considerations. In addition, the study includes an analysis of the toxicity and health implications of the constituent materials of chaff and flares, as well as the by-products of their use. Safety issues and their risks are also being evaluated.

The study is being conducted in three phases. This Technical Report culminates the first phase, which focused on identifying environmental, health, and safety issues associated with chaff and flares use; examining the materials themselves and how they are used in training; reviewing available data, literature, and study results; reviewing regulatory and policy issues; and identifying further data needs and research efforts for resolving outstanding issues. The second phase will concentrate on specific follow-up research activities, including field studies, laboratory studies, modeling, and data collection and coordination with other federal and state agencies. The second phase will culminate in a series of topic-specific Technical Reports documenting the results of these research projects. In the third phase, all findings will be integrated into a comprehensive summary report that can be used in preparing future EAs and EISs for projects involving chaff and flares.

It is expected that the results of this study will generally fall into four categories:

(1) Issues about which sufficient data exist to conclude that there is virtually no potential for significant adverse impacts will be documented and can be incorporated by reference in future analyses.

(2) Issues that involve a definable level of risk will be assigned a hazard rating based on probability of occurrence and severity of consequence.

(3) For issues about which conclusions can only be reached on a site-specific level, guidance will be provided on data to be collected and methods that can be used to conduct the necessary analysis on a case-by-case basis.

(4) For issues that remain as a credible concern, potential mitigations will be identified for consideration in future training plans.

The scope of this study is focused on identifying issues and impacts unique to chaff and flares. It does not include in-depth analysis of common secondary consequences of those impacts. For example, if a flare starts a fire, the secondary environmental consequences could range from increased erosion and sedimentation to habitat alteration to property damage and injury. These types of impacts are common consequences of a fire, regardless of its cause, and have been well documented. Therefore, in this example, the study will concentrate on identifying the risk of a flare causing a wildfire that generates significant impacts, rather than on characterizing the impacts themselves, except to provide a brief summary of what they might be. As another example, while the study might identify the risk of an aircraft mishap due to chaff or flares malfunction (if such a risk exists), it would not analyze the potential consequences of a resulting fuel spill on the environment. Limiting the scope of the analysis in this manner allows the study to concentrate on considerations important to making decisions about chaff and flares use.

1.2 APPROACH

The approach employed in this study to identify potential impacts from chaff and flares use, analyze their likelihood of occurring, and reach conclusions about the resulting consequences to the environment centers around a pathway analysis. This analysis identifies the potential events that might occur in the process of using chaff and flares and defines the pathways by which resulting materials and by-products could enter the environment and affect specific resources. The pathway analysis identifies both primary media — air, land, and water — and secondary means — uptake, inhalation, ingestion, dermal contact — for chaff and flares to enter the environment and have an effect. The physical act of introducing an element into the environment is not itself an impact. There must be an effect on people or on an environmental resource to create a potential concern.

The pathway analysis is based on an understanding of how chaff and flares are designed and how they are employed in training. This is important because it defines what events have a possibility of occurring. It will also affect the probability of certain events occurring. For example, information on failure rates of chaff and flares affects the probability of failure-related consequences. If the failure rate is known to be 5 percent, it can be concluded that the probability of any impact stemming from a failure will be 5 percent or less. To the extent that probabilities can be assigned to potential events, the risks associated with resulting effects further down the "path" can be estimated or at least bounded. Risk, along with the consequences themselves, is an important aspect of assessing impact, particularly for unintended and inadvertent events such as material failure and human error.

Once potential pathways of introducing chaff and flares and the by-products of their use into the environment have been identified, resulting impacts are addressed on a resource-specific basis. For each environmental resource topic, the analysis of potential impacts is based on a combination of directly applicable data, such as actual studies on chaff and flares, and indirectly applicable data, such as general knowledge about the behavior of environmental elements (wind, water, etc.) and receptors (plants, animals, humans). Thus, conclusions about some potential impacts may be based on physical or behavioral information, even though no studies directly involving chaff and flares have been conducted. In some cases, limited follow-on research is recommended to verify the conclusion.

Environmental effects can be acute and manifest themselves in the short term, or they can evolve over the long term. Most past studies on chaff and flares have concentrated on acute effects and effects of a single event or a finite number of events. Even discussions of accumulated effects have been limited to one year or less (e.g., the number of chaff bundles or flares used over a year). Almost nothing has been done to assess the long-term effects of continuous chaff and flares use on either the accumulation of residual debris or the chronic effects of this accumulation on such things as soil and water chemistry and wildlife physiology. To the extent practicable without long-term research, this study will address these issues of long-term effects.

The first phase of this study has been primarily a review of past studies, reports, and available data. The review of existing literature was conducted critically, with the objective of determining whether the data are adequate to support a conclusion, or whether more extensive (or different) research is needed. It was not anticipated that this first phase would yield adequate results to resolve all issues concerning potential impacts from chaff and flares on the environment. In most cases, available data and literature are not absolutely conclusive. Some data have been requested but not yet received. Therefore, although this report is intended to culminate the first-phase data collection effort, it is expected that new data will continue to be acquired, and findings and conclusions will need to be updated.

The initial effort has resulted in some conclusions that must be considered preliminary. In order to assist in determining what might be a reasonable level of additional effort, commensurate with the importance of the issue and the risk of adverse effect, the conclusions are presented in terms of level of concern, from negligible to high. This classification incorporates consideration of the sensitivity of an issue (e.g., an effect on threatened and endangered species is a more sensitive issue than an effect on a non-listed species), risk (probability) of occurrence, and severity of impact. Thus, it may be interpreted as an indication of the amount of supporting data required to reach a defensible conclusion. As such, the conclusions presented in this report should be examined critically, and decisions about additional research needs should reflect the goal of compiling adequate documentation to support training activities.

1.3 DATABASE RESOURCES

A bibliographic database has been compiled specifically for this study to provide a central listing of citations, reports, and other documents identified and used in the analysis. A printout from this database is provided in Appendix A. This printout also serves as the reference list for text references in this report. The database will be updated continuously as the study progresses and included in future Technical Reports.

In addition to reviewing existing documents and other literature for this report, a number of computerized databases were accessed to search for relevant information or references. Resource-specific databases are described in the applicable resource sections of Sections 4.0 and 5.0. A general database, the DIALOG Information Retrieval Service, was used in a number of resource areas. DIALOG is an online information service for technical researchers. The DIALOG menus offer a selection of over 300 databases on science, technology, business, chemistry, engineering, and news. Many of the databases in DIALOG contain information abstracts describing published research and cover trade journals, research publications, and patents. Appendix B provides a list of DIALOG databases accessed for this report.

Another significant database accessed in completing this report is the online Toxicological, Occupational Medicine, Environmental Series (TOMES), which was accessed for information on the toxicity of the materials in chaff and flares. TOMES comprises a number of databases, listed in Appendix B. A computerized bibliography of approximately 30,000 citations dealing with fire issues was also acquired from the International Association of Wildland Fire.

1.4 ORGANIZATION AND CONTENT OF THIS REPORT

Technical Report No. 1 contains eight chapters and six appendices. After this introduction, Section 2.0 provides a summary of chaff and flares use in ACC training. Chaff and flares differ from one another in composition and how they behave in the environment, but operationally, they are usually used together in training. Therefore, Section 2.0 describes training activities applicable to both chaff and flares and provides a basis for analyzing the potential pathways to environmental impact.

Section 3.0 summarizes regulatory and policy considerations that apply or may apply to chaff and flares use. The applicability of some legislation and regulation, and the approach to compliance, depend in part on whether or not there are actual impacts on protected resources. However, this section provides an overview of regulatory considerations that could affect the use of chaff and flares.

The next two sections present data and findings specific to chaff (Section 4.0) and flares (Section 5.0), beginning with a pathway "road map," followed by a detailed description of the materials involved. Data on the toxicity of the constituent materials are also provided. Each section then addresses issues and data related to safety, air quality, physical resources (soil and water), biological resources, land use and visual resources, and cultural resources. Section 5.0 also contains a discussion of fire hazards. Each resource subsection identifies issues pertaining to chaff or flares use, summarizes existing literature/information, discusses data gaps and unresolved issues, and presents conclusions and recommendations, including potential follow-on research.

Following the detailed analysis, Section 6.0 summarizes the conclusions reached from the available data and prioritizes projects to be considered for future activities, including Phase 2 research. This section also identifies mitigation measures that could be used to reduce identified risks and avoid extensive compliance requirements. Section 7.0 lists persons contacted and 8.0 identifies the scientists and specialists who performed the research and analysis for this report.

Some additional background information is included in appendices. As noted above, Appendix A provides a database of literature sources identified in the course of conducting the Phase 1 effort and used as references in the analyses presented in this report. This database will continue to be updated as the study progresses and additional sources are identified. Appendix B identifies other databases accessed. Appendix C provides a short description of ranges and airspace areas identified by ACC units as used for chaff and flares training. Appendix D lists the laws, regulations, Executive Orders, cases, and other citations referenced in Section 3.0. Appendix E presents supplemental toxicological information on toxic substances found in the pyrotechnic devices used to dispense chaff and flares, and Appendix E provides a summary of Air Force Regulation (AFR) 127-4, which was used for the safety analyses.

2.0 CHAFF AND FLARE USE IN TRAINING

This section provides a summary of how chaff and flares are used in training, what restrictions are currently placed on their use, where ACC training with chaff and flares currently takes place, and the experience ACC units have had with environmental impacts. This information was collected by sending a questionnaire to all ACC installations and conducting interviews with a number of ACC ranges where chaff and flares are employed.

The questionnaire was forwarded by Headquarters ACC to each base environmental office for coordination with appropriate personnel in range and airspace management, safety, weapons, tactics and operations, supply, and other offices as necessary. The type of information requested included the following:

- Ranges, MOAs, MTRs, and other areas where chaff and flares are being employed by each flying unit.
- Types of aircraft using chaff and flares.
- Types of mission profiles and typical altitudes of use.
- Types and quantities of chaff and flares employed annually and the relative proportion used at each location.
- Specific local procedures or policies governing chaff and flares use, such as minimum drop altitudes, area, or seasonal restrictions.
- Past or present problems or issues resulting from chaff or flares use, such as fires, safety hazards, interference with radar or communications systems.
- Local studies or environmental documentation discussing effects of chaff or flare use.
- Future status of unit's chaff or flare use, including any anticipated significant changes in use, changes to procedures, or changes in areas of use.

Subsequent contacts were made with base and ACC personnel to discuss responses to the questionnaire and obtain additional information as needed to fully characterize chaff and flare use throughout the Command. Air Force, Major Command, and local regulations were also reviewed, along with other materials and correspondence provided.

This section provides a compilation of this data collection effort to the extent that information was available. Some data gaps exist where the requested information was not fully known or could not be provided within the initial data collection phase of this study.

2.1 PURPOSE OF USE

Chaff is dispensed from combat aircraft as a defensive mechanism to avoid detection by ground-based or airborne radar systems. Self-protection flares are devices ejected by aircraft as a means of misleading the guidance systems of heat-sensitive or heat-seeking targeting systems. The effective use of chaff and flares in combat requires training and frequent use by aircrews to master the capabilities of these devices and to ensure safe and efficient handling by ground crews. Training is conducted through simulated battle conditions within weapons or electronic combat ranges and within other airspace areas, such as MOAs, MTRs, and other designated areas that have been assessed and approved for chaff or flare use. Chaff and flares are also used in field exercises such as Red Flag on the Nellis Range.

When ejected from an aircraft, chaff forms the electromagnetic equivalent of a visual smoke screen that temporarily hides the aircraft from radar. It consists of small, extremely fine fibers of aluminum or aluminum-coated glass fibers that disperse widely in the air when ejected from the aircraft and effectively reflect radar signals in various bands, in order to create a very large image of reflected signals ("return") on the radar screen. In the air, the initial burst from a chaff bundle forms a sphere about 300 feet in diameter. This sphere shows up on radar screens as an electronic cloud. The aircraft is obscured by the cloud, which confuses enemy radar. Since chaff usage can obstruct radar, its use is coordinated with the Federal Aviation Administration (FAA).

Self-protection flares are magnesium pellets that, when ignited, burn for a short period of time (less than 10 seconds) at 2,000 degrees Fahrenheit (F). The burn temperature is hotter than the exhaust of an aircraft and therefore attracts and decoys heat-seeking weapons targeted on the aircraft.

Another self-protection mechanism is the "smokey devil," which creates a literal (visual) smoke screen when dispensed from certain aircraft.

Types of chaff used by various aircraft are described in Section 4.2, and types of flares are described in Section 5.2.

2.2 FLIGHT PROFILES FOR DISPENSING CHAFF AND FLARES

Chaff and flares are used by fighter and bomber units over a wide range of altitudes and flight maneuvers or tactics. Deployment of chaff and flares does not interfere with the flight characteristics of the dispensing aircraft. Fighters can drop chaff or flares at any approved altitude during any flight maneuvers (turns, climbs, descents), airspeed, and G-loading. Although less maneuverable than fighters, B-1Bs and B-52s can drop chaff or flares at any approved altitudes while in a turn, climb, or descent. Specific descriptions of how chaff or flares are actually employed in training for a combat situation are not releasable.

During peacetime operations, the particular altitude profile typically flown by each fighter or bomber unit is generally dependent on the availability of different range and airspace capabilities. For instance, B-52Gs at Castle AFB drop chaff on virtually all training missions except local sorties in the traffic pattern. This includes their low and high level flight envelope in which they drop from 500 feet above ground level (AGL) to 40,000 feet mean sea level (MSL). Flares drops are accomplished almost exclusively during low level flight (500 to 2,000 feet AGL). Other heavy bomber units use a similar altitude envelope on a variety of ranges, MOAs, and Warning Areas. Bomber aircrews train for low and high ordnance deliveries in which they would use chaff and flares to defeat ground based radar and airborne radar systems. Fighter Intercept Exercises (FIEs) and Red Flag and Warfighter exercises are normally the high-use profiles for chaff and flares.

Altitude envelopes between fighter and bomber type aircraft are similar. Typical altitudes and airspeeds provided by Nellis AFB personnel are:

- Low Altitude — surface to 5,000 feet AGL, 500-600 knots for fighters and 200-400 knots for B-52s and A-10s.
- Medium Altitude — 5,000 feet to 15,000 feet/25,000 feet, transonic airspeeds of 0.8 to 0.9 mach.
- High Altitude — 15,000 feet/25,000 feet to aircraft service ceiling, at or near 0.8 to 2.0 mach.

Fighter aircraft flight profiles are more diverse in vertical movement than bomber profiles, due to their low altitude air-to-ground and higher altitude air-to-air roles. Fighter-type aircraft may ingress to a low level target at 200-300 feet AGL and 480-600 knots to establish their climb angle, climb to 4,000-4,500 feet AGL, release the weapon, execute a hard turn while descending to 200-300 feet AGL, with multiple hard turns to exit the target area. Chaff will probably be released as the initial climb is established, just prior to weapon release, post weapon release, and as the hard turns are executed. If target defenses contain infrared (IR) capability, flares will be dispensed in place of chaff. High altitude ingress to a target area may require a "combat descent" to the target or to a lower approach altitude. Depending on the defensive capabilities of the target area, chaff and/or flares may be used in the descent. Aircraft dependent, the descent may be accomplished at 30-60 degrees or near vertical angle at airspeeds ranging from 500-600 knots to supersonic speeds.

During air-to-air combat tactics, the altitude envelope typically increases to the middle and upper altitude structure. Chaff and flares may be used during the employment of Air Combat Tactics (ACT) or Offensive Counter Air, in which one aircraft opposes one other aircraft, two aircraft oppose two other aircraft, or any number of aircraft oppose some number of others.

2.3 CURRENT RESTRICTIONS ON USE OF CHAFF AND FLARES

Restrictions governing chaff and flare use are based primarily on safety and environmental considerations and limitations. General baseline guidance and restrictions have been established at the Air Force or Major Command level, and units have supplemented these procedures as necessary for their particular ranges or other training locations. General procedures are described below; any specific procedures for individual training areas are provided in Appendix C.

2.3.1 Chaff

AFR 50-46, dated 8 June 1987, outlines procedures governing weapons range use and states that chaff may be dropped only if specifically authorized for use on the range and when ground impact will occur on government controlled land, inhabited areas are not overflown when ejecting chaff, and wind conditions and locations of sensitive electronic equipment are considered to preclude inadvertent degradation or damage. These conditions are contingent on the types of chaff used, since certain types may require more stringent restrictions.

Nellis Supplement to AFR 50-46 indicates that more recent Air Force guidance permits use of self-protection chaff on all approved ranges and MOAs between 300 feet AGL and 25,000 feet MSL. It cannot be dropped over Wilderness Areas, Wilderness Study Areas, National Parks, and populated areas.

AFR 55-79, dated 17 August 1992, delineates procedures for chaff, flare, and smokey devil employment. It prohibits arming of dispensing systems unless in an approved area with intent to dispense.

Headquarters Strategic Air Command (SAC), Offutt Air Force Base (AFB) message dated 15 November 1991, titled "Local Restricted Band ECM Clearance and RR-112 Chaff Clearance SAC 91-003," continues to be used as guidance for dropping of RR-112 chaff. This message authorizes the dropping of chaff throughout the continental United States within the cleared areas from an altitude of 500 to 40,000 feet AGL. Exceptions specify that no chaff drops are authorized within 30 nautical miles (nm) of precision approach radar sites, and chaff drops within the White Sands Missile Range must be coordinated with White Sands at least one day prior to the drop (AFR 55-44).

2.3.2 Flares

AFR 50-46 states that flares may be dropped only on weapons ranges if specifically authorized for use on the range and when ground impact will occur on government controlled land, ground personnel safety is assured by avoiding their overflight or by ejecting flares at an altitude that assures burnout before ground impact, and fire hazard is minimized by ejecting flares at an altitude that assures burnout while airborne when flammable material exists on the ground. These conditions are contingent on the types of flare used, since certain types may require more stringent restrictions.

AFR 55-79, in addition to prohibiting arming of flare systems except in approved areas with intent to dispense, sets certain conditions for employment of flares and smokey devils. Flares are authorized over government owned and controlled property and overwater Warning Areas, with no minimum altitude restrictions when there is no fire hazard. If a fire hazard exists, minimum altitudes will be maintained in accordance with the applicable 55-series directive or range order. Original manufacture smokey devils can only be employed in these areas at 500 feet AGL or higher. Designated Value Engineering Change Proposal Smokey Devils and flares may be employed in training areas that are not government owned or controlled only if an Air Force Form 813, Request for Environmental Impact Analysis, has been submitted and approved. A minimum altitude of 300 feet AGL is specified for this particular smokey devil.

Tactical Air Command Regulation (TACR) 55-79, dated 6 August 1990, outlines flare employment restrictions on ACC ranges as shown in Table 2.3-1. It also includes a caution for avoiding flare/chaff/smokey devil collision.

Table 2.3-1. Flare Restrictions on ACC Ranges

Condition	Minimum Altitude	
Government owned or controlled land where fire hazard exists (e.g., ranges or Restricted areas).	RF-4C/OA/A-10 F-4 F-15/F-16/A-7 F-111 w/ALE 28 F-111 w/ALE-40	400 feet AGL 600 feet AGL 700 feet AGL 900 feet AGL 700 feet AGL
Government owned or controlled land where no fire hazard exists.	No restriction	
Non-government owned or controlled land (e.g., MOAs, MTRs, Warning Areas, and non-government lands beneath some Restricted areas).	2,000 feet AGL; F-111 w/ALE-28 prohibited	
Ranges, MOAs, MTRs or Warning Areas which are over water.	No restriction	

Strategic Air Command Regulation (SACR) 51-5, Vol. I (classified SECRET) generally states that flares can be dropped within special use airspace only, and over water at least 50 nm from the shoreline and at least 25 nm from airways and corridors.

2.4 CURRENT AND HISTORIC USE OF CHAFF AND FLARES

Tables 2.4-1 and 2.4-2 show the amount of chaff and flares reported to have been used annually by ACC units within various ranges, Restricted and Warning Areas, MOAs, MTRs, and other specially designated areas. These cumulative amounts are estimated, based on the actual or allocated use of each type of chaff and flare by each ACC fighter and bomber base. Although the amounts are estimated and do not include non-ACC users, the tables provide an overview of the locations used and relative proportion of use for each area. Base closures and related aircraft realignments have or will be transferring chaff and flare allocations to gaining bases, but future levels of use are generally expected to be the same as present levels.

The areas listed in Tables 2.4-1 and 2.4-2 are shown on Figure 2.4-1. Brief descriptions of each area and any restrictions on chaff and flares use are provided in Appendix C.

2.5 PAST EXPERIENCE WITH IMPACTS

A survey of ACC units uncovered site-specific impacts, problems, or issues with either chaff or flares. Those that were identified are described below.

2.5.1 Interference with FAA Radar Systems

A combination of factors, including FAA chaff use restrictions/limitations, a depletion in the inventory of acceptable types of chaff, and outdated or inconsistent procedural guidance have made the use of chaff an issue for the Air Force. In recent years, the FAA has placed more stringent restrictions on the Department of Defense's (DOD) use of any type of chaff that operates within the bands used by air traffic control radar and navigational systems. In taking the more conservative approach to air traffic control and flight safety, the FAA has limited or placed restrictions on the locations, altitudes, and/or time periods within which specific types of chaff can be employed. Incidents have been reported at Phoenix and some other locations over recent years where chaff may have caused interference with the FAA's radar systems. However, discussions with ACC flying units and staff members and Air Force Representatives at the FAA Regional Headquarters indicate that very few reported occurrences of such interference were attributable to known chaff operations. The Air Force is concerned that possibly unreasonable restrictions are being placed on chaff operations without substantial reason.

The Spectrum Management Office (ASM-500) at FAA Headquarters in Washington, D.C. is the approving agency for DOD chaff use requests. These requests are forwarded through appropriate channels to this office, where they are reviewed relative to the types of chaff to be used, requested area and altitudes, dates and times of employment, and other operational data that accompany the military request. After considering the requested action's potential to interfere with any of the air traffic control equipment frequency bands, each request is either approved, denied, or approved with certain restrictions, such as time or altitude limitations. Once the request has be acted upon and has been approved to any extent, a copy of the request

Table 2.4-1. Annual Chaff Use

Location	CHAFF USE (Annual number of bundles)					
	RR-72	RR-112	RR-129	RR-141	RR-144	RR-170
Nellis Range*			5,120	7,944		478
Utah Test and Training Range				60		100,430
Saylor Creek Range				67		5,935
Melrose Range						5,000
Yuma (R 230/W)						2,500
Goldwater Range/Sells MOA						57,972
Superior/China Lake Ranges						1,200
Fallon Ranges						800
Moody 1/3 MOAs						26,000
Tiger MOA		2,400				1,100
Big Ben MOA		2,400				
Ada MOA						1,200
Salem MOA						1,200
Powder A/B MOA		1,200	720		100	720
Hays MOA		7,000				
Ellsworth Area	10,000	21,800				31,120
Griffiss Area		26,756				

*Additional chaff for Nellis Range includes 30,000 Speed Brake, 104 RR-119, 20,604 RR-136

Table 2.4-1. Annual Chaff Use (continued)

CHAFF USE (Annual number of bundles)						
Location	RR-72	RR-112	RR-129	RR-141	RR-144	RR-170
W-151**		10,000				1,230
W-157						12,850
W-161 A/B						56,610
W-177 A/B						56,610
W-470		90,000				27,300
W-108						20,475
W-386						20,475
W-122						20,475
W-570		8,400				
IR-300***		2,700				
IR-302		2,700				
IR-293		1,800				
IR-320		1,800				
IR-800		3,640				

**W denotes the designation for a Warning Area
***Instrument Route MTR

Table 2.4-2. Annual Flare Use

FLARE USE (Annual)										
Location	ALA 17A/B	MJU-7/B (Para/non-Para)*	M-206	M-206 (T-1)	MJU-2	MJU-7 (T-1)	MJU-8	MJU-10	MJU-23	MJU-33
Nellis Range	118	30,451/ 47,030	23,838	3,113	6,776	369	2,612	1,833		50
Utah Test and Training Range	530	45,955	650							50
Saylor Creek Range	200	1,100	650							
Melrose Range		200								
Goldwater Range/Sells MOA			85,326							
Superior/China Lake Ranges	29									
Fallon Ranges	29	370								
Poinsett Range			2,500							
Lake Superior Range (R-4305)	640									
Lake Superior/ Michigan	144									
Moody 1/3 MOAs		16,200								
Gamecock MOA										
Powder A/B MOA										
WSMR (Lava and Yonder)		3,420								
W-151		3,000							3	
W-170									2	
W-102	296									
W-105	296									

*Parasitic/non-parasitic — specified only by Nellis; other locations unknown. Parasitic flares are ignited upon ejection; non-parasitic flares ignite after leaving the aircraft

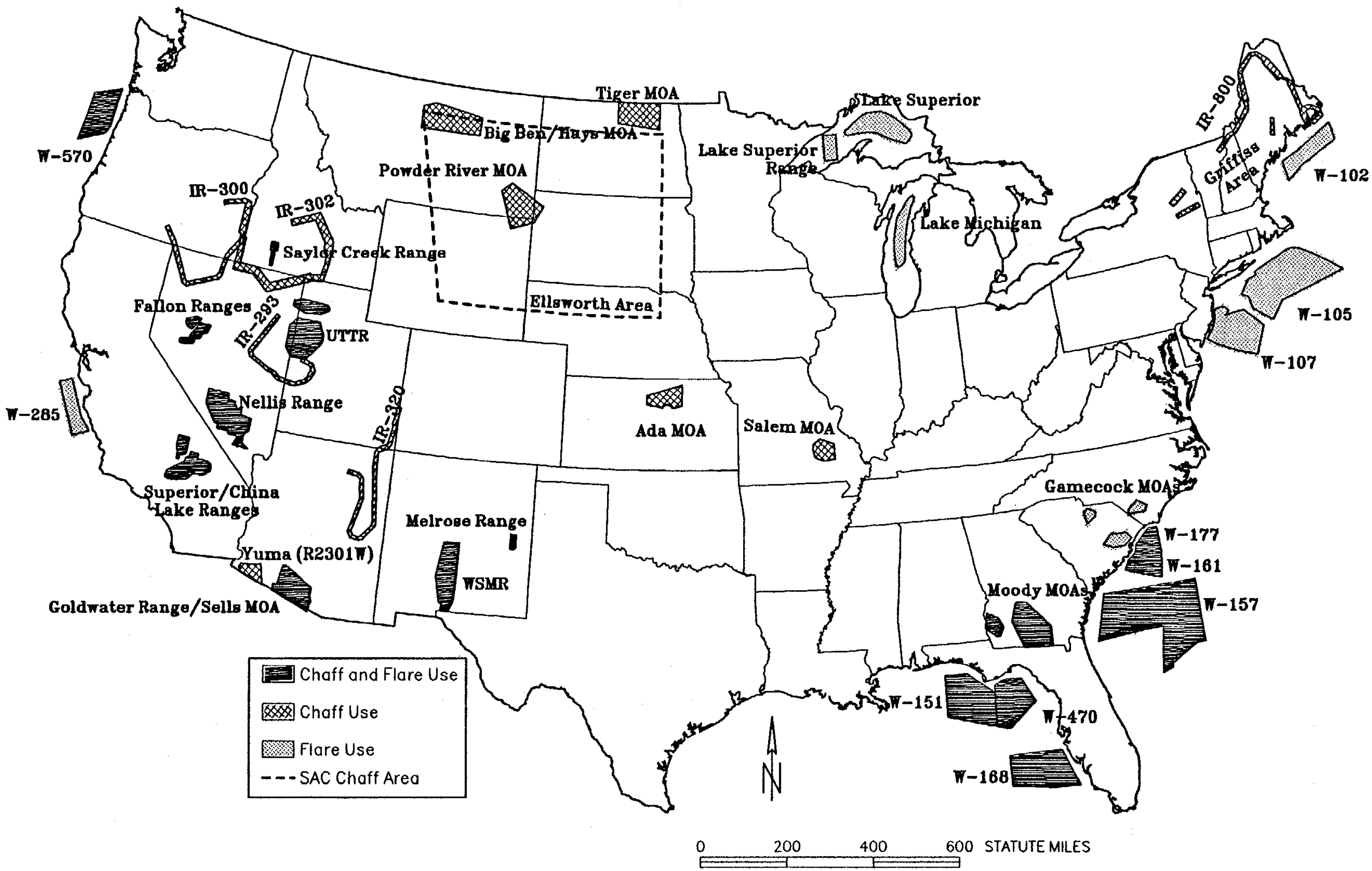
Table 2.4-2. Annual Flare Use (continued)

Location	FLARE USE (Annual) ALA 17A/B	MJU-7/B (Para/non-Para)*	M-206	M-206 (T-1)	MJU-2	MJU-7 (T-1)	MJU-8	MJU-10	MJU-23	MJU-33
W-107	40									
W-168		7,000								
W-157		6,500								
W-161A/B		8,350			3,000		1,600			
W-177A/B		8,350			3,000		1,600			
W-285	160									
W-470		36,700								
W-570	1,200									

*Parasitic/non-parasitic — specified only by Nellis; other locations unknown. Parasitic flares are ignited upon ejection; non-parasitic flares ignite after leaving the aircraft

Langley AFB use of MXV-8 at W-108, 386, 122 — total use is 17,054.

Figure 2.4-1 Location of Chaff and Flares Training Areas



is provided to Air Traffic Management (ATM-400) for coordination and appropriate action by the affected air traffic control facility. In some cases, Notice to Airmen (NOTAM) may be required to advise the flying public that certain air traffic control equipment or services may be affected during a specified period of time by chaff operations.

While the FAA has taken a more restrictive approach to chaff use in recent years, FAA officials feel they try to be reasonably considerate of military training needs. The Spectrum Management Office has been working with requestors to accommodate chaff use. The FAA has indicated that they have been able to approve, with added restrictions as necessary, many of the DOD's chaff clearance requests. These restrictions, however, have not always been suitable to the user and have often imposed conditions (altitudes, locations, or times) or constraints (depletion of chaff supplies) that are not compatible with some military training requirements.

As FAA restrictions are imposed on the types of chaff that can potentially interfere with FAA equipment (e.g., RR-129, RR-170, and RR-180), available inventories of acceptable types (e.g., RR-117 and RR-141) are being depleted. There is a newer type of chaff (RR-188) under development that will not interfere with the affected frequency bands; however, it is not yet in the supply system. Therefore, the depleted supply or nonavailability of acceptable types of chaff and restrictions on the use of other types are causing some problems in accomplishing chaff training requirements among ACC units.

There has been a continuing dialogue between FAA and the military services through joint service users' group meetings on the chaff use issue. This process may have been hindered somewhat by the consolidation of Tactical Air Command and Strategic Air Command under Air Combat Command in regards to establishing more centralized awareness and control over the general use of chaff by tactical and bomber aircraft. Procedures and practices that have historically been in use by the respective commands are coming under review and will eventually be consolidated under ACC directives. Air Force Manual (AFM) 55-44 contains guidance on chaff use, but this publication is outdated and is in the process of being revised to incorporate more recent FAA direction. Through the combination of continued DOD-FAA dialogue, the ACC reorganization processes, and procedural review and updating, it appears that some progress is being made towards resolving some of the chaff use issues.

2.5.2 Training/Combat Operations Impact

The ALQ-153 is the tail warning system (TWS) for the B-52G/H. This system identifies hostile threats behind the aircraft and automatically dispenses chaff and flares. The Western Area Power Administration (WAPA) has effectively blocked the use of the ALQ-153 within much of the north and central U.S., including the Powder River MOAs. B-52 aircrews receive little training in this system. Their training is currently limited primarily to simulators that represent a "perfect" operating system. ALQ-153 operations are restricted to specific geographical areas within the U.S. to prevent frequency interference between the ALQ-153 hardware and WAPA's microwave relay stations. Most of these cleared areas are of no practical training value to B-52 crews because the areas are not within their designated exercise areas, such as the Powder River MOAs. The Nellis Range and the Utah Test and Training Range (UTTR) are designated as cleared areas but are used primarily for exercises focused on providing combat experience to aircrews, rather than providing airspace to train crews in equipment operation and tactics (Source: Message from 25FTTS/WFF 2/23/93).

2.5.3 Expended Flare Residue Safety and Environmental Impacts

Nellis AFB retains a self-imposed restriction of dropping only M-206 and the "MBT" lot designation of the MJU-7 flares in their MOAs. All other MJU-7 (non-MBT lot) contain a mechanical safety and initiation device (see Section 5.2). This device is not consumed during the flare burn and falls to the ground as debris. Nellis safety personnel are concerned about the risk posed by the flare debris to people and property under the MOAs. Additionally, there is a potential concern about the environmental classification of flare debris.

3.0 REGULATORY AND POLICY CONSIDERATIONS

This section addresses the statutes, related regulations, and policy issues arising from use of chaff and flares. It emphasizes issues related to chaff and flares use outside military ranges, particularly in MOAs and MTRs over private property and non-military federal lands. However, most of the regulatory issues are equally applicable to military lands, since environmental laws apply regardless of location. The purpose of this section is to identify potential problem areas; it is not intended as a complete legal analysis. Site-specific legal analysis by government legal officers is essential as a component of the Air Force Environmental Impact Analysis Process (EIAP).

This section also reviews issues of liability associated with chaff and flares use. Whether to assume the risk of incurring damage claims is a policy decision. It should be made in consultation with legal counsel. The discussion of liability issues in Subsection 3.2 is intended to assist in understanding the legal principles involved.

A list of laws, regulations, cases, and other citations referenced in this section is provided in Appendix D.

3.1 LAWS AND REGULATIONS POTENTIALLY AFFECTING USE OF CHAFF AND FLARES

The applicability of specific laws and regulations depends in part on actual impacts that may occur. Use of chaff may cause radar interference, short-circuiting of electrical equipment on which it happens to drift, concentration at fencelines and ditches in open country, and possible effects on animal and marine life. Flares burn at very high temperatures and can cause fires in dry vegetation. Existing Air Force regulations require flares to be used at altitudes that should prevent ground ignition, but when high performance aircraft are flown relatively close to the ground, errors can occur. Flares emit combustion products of magnesium and other chemicals while burning. Small plastic caps and other debris do not burn and are deposited on the ground or water underneath. Occasionally, a flare will not ignite when fired and will end up on the ground as a dud, still ignitable under some circumstances. Magnesium (the primary component of the flare) combines with water to form hydrogen, a fire and explosion hazard.

The extent to which the regulatory issues discussed in this section are serious problems depends on the likelihood, frequency, and severity of these effects on a particular portion of the environment under specific operational circumstances. The specific circumstances of the proposed use and the anticipated occurrence of the related effects must be assessed in determining whether there is a regulatory problem. This section introduces a spectrum of potential issues, but each has to be evaluated on a site-specific basis.

Chaff and flare use is not directly regulated by other than Air Force regulations. Air Force operational regulations, such as AFRs 50-46 and 55-79, address how they will be used.

Regulation under environmental, pollution, and land use laws has not occurred. This section, therefore, considers how various existing laws might be applied, and offers some suggestions on the probability and implications associated with their application.

3.1.1 National Environmental Policy Act

The National Environmental Policy Act (NEPA) of 1969 (Public Law [P.L.] 91-190, 42 United States Code [USC] 4321-4370a) is a procedural law, imposing no environmental standards but strictly mandating preparation and (in most circumstances) publication of formal statements describing a proposed federal action, alternatives to it, and environmental effects (or impacts) of the proposal and alternatives. These documents must accompany the proposal through the agency review process, so that environmental impacts will be addressed to the same extent as policy, budget, and political considerations.

NEPA applies only to federal agencies. Private parties are not required to do federal environmental documents (some states, such as California, require private environmental impact reports). Where a private action is federally regulated, or a federal decision affects an otherwise private action, NEPA applies to the federal decision.

The Council on Environmental Quality (CEQ) promulgated Regulations (40 Code of Federal Regulations [CFR] Parts 1500-1508) for implementing NEPA, which are, in turn, implemented for the Air Force by AFR 19-2. These regulations require all proposed actions to be "assessed" in an EA to determine whether they may have a significant environmental impact. As an initial step, actions that seem minor may be matched with a list of Categorical Exclusions (CATEX) contained in AFR 19-2 of actions previously assessed by the Air Force and found to lack any adverse environmental impact. Those actions require no further documentation. An EA does not require original research, but it does have to accurately determine what effects the action may have and correctly set out the reasonable alternatives to it. Once an EA is prepared, a decision is made whether or not there is a "significant" environmental impact. If not, a Finding of No Significant Impact (FONSI) is executed, and the action may proceed. If it appears that there may be a significant impact, the EIS process begins. Due to extensive procedures for public notice and interaction required for EISs by the CEQ Regulations, the process takes at least six months, rarely less than nine months, and normally a year or more. During that time, the decision cannot be made nor the proposed action implemented.

Courts review compliance with NEPA largely for two issues: (1) whether a proposal is a "major federal action" that may have a significant (adverse) impact on the quality of the human environment, thus requiring a formal EIS, and (2) whether an EIS, when one has been prepared, "adequately" discusses the proposed action, the reasonable alternatives to it, and the reasonably foreseeable environmental impacts of the proposed action and alternatives. There are no fines or penalties for violating NEPA, only an injunction (judicial order) against the project until deficiencies in NEPA compliance are remedied.

There are no quantitative standards for "significant" adverse impacts or set criteria for when an alternative is "reasonable." The CEQ Regulations and AFR 19-2 provide guidelines based largely on past experience with judicial interpretations. CEQ Regulations (40 CFR 1508.27) define the term "significantly" as requiring consideration of both context and intensity. The significance of an impact (or effect — the words are used interchangeably) is site-specific. If flares can be expected to hit the surface burning, the effects will be quite different if they hit the ocean, a salt desert, a drought-stricken grassland, a mountainous coniferous forest, a mixed hardwood forest in rolling country, dairy farms, or a populated suburb. The frequency with which this happens also affects significance. A once-in-a-lifetime occurrence is different from once a week. Public concern about possible effects, unwarranted by demonstrable fact, does not by itself require an EIS (40 CFR 1508.27(4)), but it is a factor to be considered in making a decision whether the action is significant. If an action may have significant environmental impacts in the location where it is planned to take place, an EIS must be prepared. Actions to avoid effects, such as moving to a less sensitive location, and actions to mitigate or offset the effects may be considered in deciding whether an EIS is required.

The "reasonableness" of an alternative is not defined in the law or the regulations, though it has been the focus of a number of court decisions. Essentially, if there is another method of accomplishing the proposed action that is feasible, not exceptionally costly, and produces similar benefits, even if it is less desirable, it is probably reasonable unless there are strong countervailing considerations. In the case of flare use, for example, simulation by electronic or other means, selecting other locations with less sensitive environments, and confining use to military ranges are categories of alternatives that might be regarded by a reviewing court as reasonable. If so, they would have to be discussed in EAs and EISs, even though the proponent may not favor them or contemplate adopting them. It is not unusual for alternatives to end up as the decision instead of the proposed action, so this discussion should be adequate to support such a decision.

AFR 19-2 does not specifically address the NEPA documentation required for chaff or flares use. AFR 55-79 requires an approved Air Force Form 813 for flare use over non-government controlled property. It does not require an EIS. As use is expanded to MOAs in areas of the country that are heavily vegetated and/or heavily populated, however, the chance of a potentially significant impact increases. Consideration might be given to preparation of a programmatic EIS covering the effects of chaff and/or flares use in MOAs and MTRs nationwide. Thereafter, site-specific proposals could be "tiered." EAs or EISs would briefly summarize the information in the programmatic EIS, but address in detail only new issues or subjects specific to the area in question.

3.1.2 Pollution Control — Government Regulation of Government

Regulation of federal activities by states was determined to be unconstitutional as a result of the case of McColloch v. Maryland (4 Wheaton 316) in 1819. However, Congress has the power to waive federal supremacy from state regulation by statute. It can also waive the sovereign immunity of the United States to suit without its consent, which permits states or private citizens to file suit against federal agencies for violating state or federal laws.

Regulation of one federal agency by another presents several conceptual problems for enforcement. In the Clean Air Act (CAA) Amendments of 1970, which became the model for all the pollution control laws to follow, Congress provided that federal agencies must comply with federal, state, and local "requirements respecting control and abatement of air pollution" the same as any person. This waived federal supremacy to state regulation, and also forced federal agencies to comply with federal pollution control laws. However, it could not (due to constitutional issues) permit EPA to sue DOD or other federal agencies for violation of federal laws. So it provided for citizen suits against federal agencies. Broadly construed by the courts to permit states to sue as "citizens," it brought federal violators to court even when federal authorities could not do so. All of the subsequent pollution control laws have had variations on the CAA waivers of federal supremacy and sovereign immunity.

3.1.3 Clean Air Act

The CAA (42 USC 7401 et. seq.; P.L. 90-148; P.L. 101-549) requires EPA to set National Ambient Air Quality Standards (NAAQS) — descriptions of clean air, which must be maintained nationwide (Table 3.1-1). The NAAQS have been set to protect public health and welfare, with a margin of safety. The NAAQS currently include standards for six "criteria" pollutants: ozone (O_2), nitrogen dioxide (NO_2), carbon monoxide (CO), respirable particulates (particulate matter less than 10 microns in diameter [PM_{10}]), sulfur dioxide (SOx), and lead (Pb). These include short-term standards (1-hour, 8-hour, or 24-hour periods) for pollutants with acute health effects, and long term standards (annual average) for pollutants with chronic health effects. In addition to the federal standards, various states have adopted ambient air quality standards which are either as stringent or more stringent than the NAAQS. Under CAA, each state develops a State Implementation Plan (SIP) setting out the specific measures to be taken in each area of the state that is not in compliance with the NAAQS.

EPA also establishes standards for new sources of criteria pollutants. Air pollution emitters are divided into stationary and mobile sources (automobiles and some airplanes). While mobile sources are very significant contributors to urban air pollution, states cannot regulate exhaust or other emissions from tailpipes. They are established by EPA. (California, however, has a statutory waiver allowing it to set different standards than EPA's.) Military aircraft and engines are not subject to CAA regulation by either the states or EPA. 33 USC 7571 provides for establishment of standards for aircraft engines. However, Section 7572 provides for enforcement only through the civil aircraft certification process, which does not apply to military aircraft. As a result, EPA has never issued any standards specific to military planes.

CAA (42 USC 7491) states that it is a national goal to prevent any further impairment of visibility within federally mandated Prevention of Significant Deterioration (PSD) Class I areas from manmade sources of air pollution. Visibility impairment is defined as (1) a reduction in regional visual range and (2) atmospheric discoloration or plume blight (as from aircraft exhaust trails). Criteria to determine significant impacts on visibility within Class I areas usually pertain to stationary emission sources. Mobile sources are generally not subject to permit requirements.

Table 3.1-1. Ambient Air Quality Standards

Air Pollutant	Averaging Time	Federal NAAQS	
		Primary (>)	Secondary (>)
Carbon Monoxide	8-hour 1-hour	9 ppm 35 ppm	9 ppm 35 ppm
Nitrogen Dioxide	Annual	0.053 ppm	0.053 ppm
Sulfur Dioxide	Annual 24-hour 3-hour	0.03 ppm 0.14 ppm ---	--- --- 0.5 ppm
PM_{10}	AAM[2] 24-hour	50 $\mu g/m^3$ 150 $\mu g/m^3$	50 $\mu g/m^3$ 150 $\mu g/m^3$
Ozone	1-hour	0.12 ppm	0.12 ppm
Lead	Calendar Quarter	1.5 $\mu g/m^3$	1.5 $\mu g/m^3$
Gaseous Fluoride (as HF)	12-hour 24-hour 1-week 1-month	--- --- --- ---	--- --- --- ---

[1]Annual geometric mean
[2]Annual arithmetic mean

In both nonattainment areas (areas that do not meet the NAAQS) and PSD areas, stationary emitters of more than a specified amount of pollutants must have permits, normally from the state but in some cases from EPA. The permits are intended to be structured so that all of the allowed emissions will result in air cleaner than the NAAQS.

The 1970 Amendments to CAA authorized EPA to set standards for air toxics (also known as hazardous air pollutants). The Clean Air Act Amendments of 1990 constitute a renewed commitment by the federal government to establish a workable framework to achieve attainment and maintenance of "health protective national ambient air quality standards." Title III (42 USC amended Section 112) specifically listed 189 air toxics, identified on the basis of their contribution to health risk, and required EPA to set standards for them. All major stationary sources will be required to obtain an operating permit under Title V of the Act. The EPA will set Maximum Achievable Control Technology (MACT) standards for major stationary source categories that emit toxics. The MACT standards are for stationary sources only, not mobile sources.

Although mobile sources, such as aircraft, are generally exempt from air pollution permitting and emission control requirements, the emissions from the operation of these sources are included in the state's emission inventory and require permits under the CAA. It appears that burning flares constitute a "stationary source." The term is defined as "any source of an air pollutant except those emissions resulting directly from an internal combustion engine for transportation purposes or from a nonroad engine or nonroad vehicle...." The flare is not an internal combustion engine. Aircraft emission standards cover only aircraft engine exhaust, not all substances that might be emitted by or from an airplane. Therefore, flare emissions must be viewed as a stationary source emissions. However, the quantities of pollutants emitted by individual flares and their dispensers do not come close to the thresholds for requiring a permit, which range from 25 to 250 tons annually. The same holds true for chaff.

Impacts from chaff and flare usage would be considered significant from an air pollution perspective if they result in:

- An adverse change in air quality leading to nonconformance with CAA.
- An exceedance of any federal, interstate, state, or local ambient air quality standards.
- Significant visibility impairment in federal PSD Class I areas.

3.1.4 Water Quality

3.1.4.1 Clean Water Act

The Clean Water Act (CWA) (33 USC 1261 et. seq.) prohibits the discharge of any pollutant by any person to the waters of the United States without a permit from the state (for 39 states) or the EPA. A "discharge" is the addition of any "pollutant" to the waters of the United States from any point source. "Waters of the United States" means any surface water that is tidal, navigable, or connected in some physical way with such waters or their tributaries. Waters with some other relationship to interstate commerce are also included, such as those used by migratory birds. As a result, almost any surface water is subject to CWA. Remaining surface waters and groundwater are subject to state regulation, but it is unclear whether the Congressional consent to state regulation extends beyond the waters covered by the CWA.

Pollutant is defined as:

> dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discarded into water (33 USC 1362(6)).

Solid waste is defined in the Resource Conservation and Recovery Act (RCRA) as, among other things, "discarded material containing solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations" (42 USC 6903(27)). A point source is a "discernable, confined, or discrete conveyance." The examples include rolling stock and vessels or other floating craft, but not airplanes (33 USC 1362 (14)).

In a 1982 Supreme Court case, Weinberger v. Romero-Barcelo, where Navy use of the island of Veiques off Puerto Rico as a bombing and naval gunnery range was challenged, bombs dropped from carrier aircraft and naval artillery shells landed unintentionally in the water or sometimes were deliberately fired at targets in the water. The Supreme Court approved a District Court ruling that the munitions in question were pollutants, discharged (added) to the waters of the United States, from a point source (a vessel), thus requiring a permit even though the EPA had not promulgated any regulations setting effluent levels or providing for the issuance of a permit for this category of pollutants. The court approved the ruling that the Navy required a permit, but went on to hold that the Navy's operations did not have to be enjoined until a permit was obtained. The court found that the Navy's discharges did not adversely affect water quality, and the interests of national defense required that the Navy continue to practice.

It is arguable whether chaff and flares constitute "munitions," which are pollutants by definition, and they do not fit any other category defined by the statute or by EPA's regulations. Perhaps they could be labelled solid waste, as "solid...discarded material," but they are not from "industrial, commercial, mining or agricultural operations," and aircraft are not included in the definition of point sources.

While the law does not provide any floor for significance of a discharge, it appears from the Weinberger v. Romero-Barcelo case that impacts would be taken into account in any judicial action. Thus, the applicability of this issue depends on whether there is any demonstrable effect from chaff and flares discharges on water quality. Burning and dud flares that enter the waters of the United States are not significantly different. EPA has no standards for magnesium compounds or other key components of the pyrotechnic, and no technology-based standards for treatment can be applied to incidental dud flares.

3.1.4.2 Marine Pollution

The Marine Protection, Research, and Sanctuaries Act (MPRSA) (33 USC 1401-1445) defines dumping as "a disposition of material," without reference to use of vessels or aircraft. "Material" includes solid waste and munitions. There are not many exceptions to the requirement for an ocean dumping permit unless one is operating a vessel, and there is no exception based on quantity.

EPA regulations (30 CFR 227-228) are relatively generous in their conditions for a permit. If the waste is not forbidden, the environmental impact is not unacceptable, there is no practical alternative to ocean dumping, and the impact of dumping on recreational and economic values and on other uses of the ocean is acceptable, a permit will be granted. It will specify a disposal site that has been designated in a separate process. Persistent inert synthetic or natural materials that may float or remain in suspension in the ocean in such a manner that they may interfere materially with fishing, navigation, or other legitimate uses of the ocean may not be dumped, unless they have been treated so that they will sink to the bottom and remain in place. Otherwise, insoluble wastes are generally approved for dumping if they are of a particle size and density that they would be deposited or rapidly dispersed without damage to the biota. Conceivably this would apply to flare residue, like plastic caps, though it is assumed that the occasional dud flare would react when the magnesium contacted the water.

The incidental dropping of chaff and flare residue into the ocean following overwater use meets the definitions of ocean dumping, and the chaff may not even qualify for a permit because it could float or affect fish. It is difficult to conceive how to structure a permit for dumping the residue of chaff and flare operations into a dump site consisting of thousands of miles of ocean. The regulations authorize general permits for dumping small quantities of harmless substances when there is minimal environmental impact. General permits are usually not permits, but a rule stating circumstances under which dumping is acceptable. There are a large number of them under the CWA. However, it is not likely that there is a chaff and flare general permit. The Air Force could apply for one, but consideration should be given to the extent to which overwater chaff and flare use constitutes "dumping" and to the procedural problems associated with preparing and processing such an application.

3.1.5 Solid and Hazardous Waste Handling, Disposal, and Decontamination

There are two solid/hazardous waste laws, RCRA and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or Superfund. In general, RCRA regulates on-going disposal of solid and hazardous waste, including closing and cleanup of disposal facilities. CERCLA was passed to regulate already closed waste disposal sites. This section deals only with RCRA, since chaff and flares are currently used and projected for continued use. Past use may raise CERCLA problems, but they are outside the scope of this study.

RCRA (42 USC 6901 et. seq.) regulates the disposal of solid and hazardous wastes. Solid waste is defined as "...garbage, refuse...and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining and agricultural operations...." Hazardous waste is "solid waste...which because of its quantity, concentration, or physical, chemical, or infectious characteristics may...cause mortality or an increase in serious...illness; or...pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed." Disposal is "...the discharge, deposit...dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste...may enter the environment or be emitted into the air or discharged into any waters, including ground waters." With respect to non-hazardous waste, the primary thrust of the law is establishment of performance guidelines for disposal. The guidelines are mandatory for federal agencies, and disposal of used chaff and non-hazardous flare residue is subject to these guidelines, at least when they have been collected for disposal.

EPA has established standards for hazardous waste that include standards for general characteristics of reactivity, ignitability, corrosivity, and toxicity. EPA also lists hundreds of specific compounds that are considered hazardous. The fact that a waste is not on the list does not mean it is non-hazardous if it exhibits one or more of the four characteristics (40 CFR Part 261). Ignitability is defined as "...not a liquid and capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture, or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard." This appears to describe magnesium, but that substance is not a listed hazardous waste in the EPA regulations.

Hazardous wastes may be collected and held for no more than 90 days without obtaining a storage permit for the facility, or transporting the wastes to a permitted facility. Labeling regulations are strict, as are standards for storage facilities. Once a hazardous waste is transported, it must be the subject of a manifest that accompanies the waste to its final disposal site.

Present indications are that normal flare debris, consisting of caps and other small metal or plastic parts, is not hazardous waste. Chaff likewise does not appear to be hazardous. Duds or partially burned flares might be regarded as ignitable, especially since they burn fiercely on contact with water.

The broad definition of disposal presents some issues for flare use. When ejected from the back of an aircraft, they are arguably being disposed of. They are "discharged onto land or water" and "enter the environment." This could make the case for requiring a RCRA disposal permit, which could not be granted since areas containing thousands of square miles of land or water cannot meet the stringent rules for disposal facilities. On the other hand, practice and live bombs, missiles, tracer rounds of ammunition, and other "ignitable" munitions have been used since RCRA was passed without challenge on this ground.

Since the quantity of duds is very low, flare use might qualify for the "small generator exemption" (40 CFR 261.5) under RCRA. Most Air Force installations already generate sufficient hazardous waste to be above "small generator" limits. Formal RCRA compliance does not appear to be required for the occasional dud that strikes the ground. However, when duds are collected, they should be treated as hazardous waste, including storing them in properly permitted facilities if not disposed of within 90 days. That should pose no difficulty since they are already treated as a safety hazard by the Air Force.

3.1.6 Animal Protection Legislation

Animal protection legislation includes the following:

- Endangered Species Act (P.L.93-205, 16 USC 1531-1544); Department of the Interior (DOI) Regulations (50 CFR 450-452).

- Marine Mammals Protection Act (P.L. 95-522, 16 USC 1361-1407); DOI Regulations (50 CFR 220-230).

- Migratory Bird Treaty Act (16 USC 701 et.seq); DOI Regulations (50 CFR Part 21).

Discussion of the provisions of this legislation requires more definitive input on the effects of chaff and flares on protected animals.

3.1.7 Federal Laws Affecting Land Use and Aircraft Overflights

3.1.7.1 Wilderness Act

"Wilderness," as defined by the Wilderness Act (P.L. 88-577; 16 USC 1131-1136) is an area of federal government land managed by the Department of the Interior or the U.S. Forest Service that has been declared, by Act of Congress, to be a Wilderness Area. Within a statutory Wilderness Area, "the earth and its community of life are untrammeled by man...man himself is a visitor who does not remain." Wilderness Areas are at least 5,000 acres in extent. No structures, roads, or motorized vehicles are allowed, and mining, grazing, and forestry are forbidden. Wilderness Study Areas, apparently suitable for wilderness designation but not yet confirmed by Act of Congress, are managed as wilderness and are subject to the same restrictions.

The Wilderness Act is unclear on whether military aircraft may operate over Wilderness Areas. It bars landing of aircraft, but does not mention overflights. It includes a provision that "the use of aircraft or motorboats, where these uses have already become established, may be permitted to continue subject to such restrictions as the Secretary...deems desirable." Linking aircraft and motorboats implies that the exemption is limited to operating on lakes. This interpretation would be consistent with the prohibition of aircraft landing in the act. Some have chosen to interpret the exemption as the only authority for use of aircraft in Wilderness Areas, including overflight.

The Air Force has generally avoided low level flights over Wilderness Areas and Wilderness Study Areas as a matter of policy, while retaining the right to do so. High altitude flight, except supersonic, has been less controversial. Congress declared in the Air Commerce Act of 1926 (44 Stat. 568) that the airspace above 500 feet is public. This may apply to Wilderness Areas. The Nevada and Arizona Wilderness Acts specifically permit overflights of Wilderness Areas, subject to formal Memoranda of Understanding with the Department of the Interior. If chaff and flare use over Wilderness Areas and Wilderness Study Areas, other than the ones covered by the two state Wilderness Acts, continues to be avoided by Air Force policy or regulation, this controversy will be avoided.

3.1.7.2 Federal Land Policy and Management Act and Engle Act

Some Air Force ranges are wholly or partly on "public domain" land; that is, land that is under the jurisdiction of the Bureau of Land Management (BLM), Department of the Interior. Much of this land is desert, rocky hills, and Alaskan tundra. Most BLM land is low-grade desert grazing land, permitted in blocks of 100,000 acres or more to private ranchers. Many of the permit-holders families have held the permits for so long — since the turn of the century or even earlier — that they regard them as private property. Public land in mountains and lowland forests falls under the administration of the U.S. Forest Service (Department of Agriculture).

The Federal Land Policy and Management Action of 1976 (FLPMA) (43 USC 1701 et. seq.) was enacted to reverse historic disposal policies and treat the public domain as a public trust to be retained forever and managed wisely. Previously, land had been withdrawn from the public domain and handed over to DOD for military use without much consideration. Withdrawn land is not subject to the appropriation laws, like mining, and can be fenced, guarded, and the public excluded. In 1985, the Engle Act (43 USC 155-158) required that withdrawals for military purposes of more than 5,000 acres be approved by act of Congress. Withdrawals under 5,000 acres must be processed under the procedures of FLPMA. DOI has chosen to apply both laws to large withdrawals. FLPMA also denied the temporary use permits historically granted for military activities, and required that the land be made available only under the formal processes for withdrawals or for rights of way.

FLPMA does not give DOI control of the sky above the public domain land, nor does it forbid landing of aircraft like the Wilderness Act. However, there has been opposition in the western U.S. to bombing, gunnery, sonic booms, and other military activities over public lands. Several attempts have been made to amend the Engle Act to require an Act of Congress to approve special use airspace designations, such as MOAs and Restricted Areas.

Use of flares in airspace over public land that has not been withdrawn may raise the concern of BLM or its grazing lessees, especially if fires result. Consideration should be given to applying the same altitude restrictions over public domain land as over private land, especially during dry seasons.

3.1.7.3 Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) (P.L. 92-583; 16 USC 1451-1454) provides for state Coastal Zone Management Plans that control development and land use in a state-defined coastal zone. The definition of coastal zone in the Act includes:

> coastal waters...and the adjacent shorelands, strongly influenced by each other and in proximity to the shorelines....and includes islands, transitional and intertidal areas, salt marshes, wetlands, and beaches....The zone extends inland from the shore lines only to the extent necessary to control shorelands, the uses of which have a direct and significant impact on the coastal waters, and to control those geographical ares which are likely to be affected by or vulnerable to sea level rise. Excluded from the coastal zone are lands the use of which is by law subject solely to the discretion of or which is held in trust by the Federal Government, its officers or agents.

The state management plan is a land use plan with additional environmental elements dealing with matters like non-point pollution. State plans, including the coastal zone map, are approved by the National Oceanic and Atmospheric Administration (NOAA) under CZMA Regulations (15 CFR 921-933). NOAA has approved state coastal zones that run much farther inland than is implied by the above definition. For example, when a range of hills visible from the ocean lies a considerable distance inland, a state may include it in the coastal zone because it visually affects the use of the ocean. The 1990 amendments even encouraged review of inland coastal zone boundaries approved under the 1972 CZMA and recommend extensions farther inland if necessary for the state "to more effectively manage land and water uses to protect coastal waters" (16 USC 1455b(e)).

Nothing in the definition of the coastal zone includes airspace above the surface. Nevertheless, there have been attempts by states to control aircraft operations over the coastal zone on the grounds that they affect the coastal zone. Federal land is excluded from the coastal zone, but federal agencies must determine whether their actions are consistent with state plans. The 1990 amendments to CZMA strengthened the federal consistency requirements by providing that:

> Each federal agency activity within or outside the coastal zone that affects any land or water use or natural resource of the coastal zone shall be carried out in a manner which is consistent to the maximum extent practicable with the enforceable policies of approved State management programs (16 USC 1456 (c)(1)(A)).

A federal agency planning to carry out such an activity must furnish the state with a consistency determination at least 90 days before making a final decision. The determination is an assertion that the project is "as consistent as practical" with the state plan.

The law contemplates that agencies can be sued over the determination that the activity is as consistent as practicable. However, the first stage of dispute resolution is mediation by NOAA. If there is a final judgement of a court that the federal project is not consistent, or NOAA certifies that mediation has been ineffective in reaching a mutually agreeable settlement, the President may exclude the activity from compliance if he finds it to be in the paramount interest of the United States. The standard for "paramount interest" is so high there have been only a handful of Presidential exemptions.

The language is available in the law, therefore, for a state to try to use CZMA to prohibit chaff and flare use over its coastal zone. It could include in the plan specific prohibitions against use of chaff and flares or dropping of objects into the coastal zone. It could include altitude restrictions for such activities, on the premise that above a certain altitude the coastal zone would not be adversely affected. These prohibitions might not be successful if the objects fell on DOD owned land, since that is exempted from the coastal zone, but if there were any chance they could fall below mean high tide (where state ownership begins) they would be back in the coastal zone.

There is a long history of exclusive FAA control of airspace, and no specific language in CZMA includes activities in FAA controlled airspace in the coastal zone. It seems likely that a state plan to control activities in airspace, even if they did affect the coastal zone, would be preempted by the Federal Aviation Act. It is also possible that an Air Force consistency determination would be upheld. However, if the land affected is privately owned and not government land, a significant amount of residue could be expected to land in the water or wash into the water (non-point source control programs must be prepared by the state for the coastal zone under 16 USC 1455b(A)), or the land is a heavily used public surf fishing area, NOAA and EPA are strongly protective towards public use and exceptional environmental quality in the coastal zone.

3.1.7.4 Federal Aviation Act

The Air Commerce Act of 1926 (44 Stat. 568) declared that the sky above the minimum safe altitude of flight established by the Civil Aeronautics Authority was a public highway, and any citizen could fly over the property of another as long as he or she observed the Civil Aeronautics Authority (now FAA) rules. Today's minimum altitudes of flight, found in FAA Air Traffic Regulations (14 CFR 91.119), are as follows: except for landing and taking off, 1,000 feet above the highest obstacle within 200 feet in congested areas; in other than congested areas, 500 feet; over water and sparsely populated areas, 500 feet from any person, vessel, vehicle, or structure. This is frequently referred to as the 500 foot rule, since its primary effect on the Air Force has been in rural areas. FAA also provides for special use airspace, controlled from one location, where users may conduct low altitude or highly dangerous activities away from conflicting traffic (14 CFR 73).

FAA regulations do not appear to address chaff and flare use, or even weapons use, except by providing for special use airspace. No prohibition against ejecting chaff or flares could be located. Nevertheless, it appears that the regulations contemplate their use only in special use airspace. Whether this proposition could be successfully advanced in court is an open question, so far as could be determined.

Establishment of special use airspace must comply with NEPA. FAA's regulations require the applicant agency to be the lead agency for environmental analysis, with FAA as a cooperating agency.

3.2 LIABILITY ISSUES

Considerations of liability can have two distinct meanings: liability for injury to another party and liability for violations of laws such as RCRA. This section addresses the former. Congress shielded employees from liability to suit by injured parties seeking to collect damages from the employee's own pocket. However, under the pollution control laws, employees and military personnel are liable to prosecution under the criminal laws for personally choosing to violate the law. Prosecution is by the government, not private parties, and the penalties are fines and jail terms.

3.2.1 Liability for Damages to Property and Personal Injury

3.2.1.1 Federal Tort Claims Act

The Federal Tort Claims Act (FTCA) (28 USC 1346) provides for suits against the United States when its activities cause injuries or property damage. This Act is a waiver of sovereign immunity from suit, the principle that the government may not be sued without its consent.

FTCA gave jurisdiction over claims for personal injury, death, and property damage arising out of activities of government agencies to the District Courts. The United States was made liable for negligent (careless) acts to the same extent as any other person. The District Court applies state law as to liability and damages, except when inconsistent with the terms of FTCA or with overriding principles of national law. To avoid lawsuits and legal bills as much as possible, Congress required that claims first be submitted to the responsible federal agency. Only if it refuses to pay, or lets six months pass without an answer, may the injured party sue.

Recently, Congress provided that military and civilian federal employees are not personally liable to pay damages for actions taken within the scope of their authority. The injured party must sue the federal government under FTCA. The federal worker may still be disciplined for the action, if warranted, but that is separate from the federal court lawsuit.

The claimant must show that the government was negligent — careless or inflicted injury intentionally. In civil law generally, a party that conducts a hazardous activity is strictly liable, even without being at fault, for all the results. An explosives expert will be liable for the roof on the house next door if the expert's properly stored backyard supply explodes as a result of a manufacturing defect and blows the roof off. The expert may eventually make the manufacturer reimburse him, but in the meantime he has to fix his neighbor's roof. If the government, however, properly stores its explosives, it is not liable at all.

FTCA does not allow suits over "discretionary actions." In the case of Peterson v. United States, a B-52, flying low and 4 miles outside the prescribed corridor, frightened cows during milking. One lunged and injured Mr. Peterson; that cow and others were also hurt. The mapping radar in the aircraft had failed and the crew was proceeding as best they could, consistent with orders to carry out the mission as if it were wartime. The pilot felt he was within the corridor and at the prescribed altitude (550 feet), but he plainly was not in the corridor, and testimony that he was at 75 feet was accepted by the court. The court held that planning the flight, including laying out the corridors, was discretionary. If the corridor had been planned over the Peterson farm, and the pilot was within it and at the prescribed altitude, the government could not be liable. However, the court said that it received "the definite and firm conviction of a mistake." Since the government had negligently carried out its plan, it was liable. (Note that the negligence could be the failure of the mapping radar and not the pilot's action.)

In another case, Maynard v. U.S. (1970), an SR-71 sonic boom caused a horse to shy, throwing and injuring the rider. The court ruled that the route had been selected at the "planning level" by the Navigation Section, 9th Strategic Reconnaissance Wing, which had followed AFR 55-34 in doing so. The court held that "discretionary functions...include not just initiating programs but establishing plans, specifications, or schedules of operation to carry them out. Where there is room for policy judgement and decision, there is discretion." Since the aircraft was following the selected route, there was no operational negligence, and the government was not liable.

The concept of discretion has significant boundaries, however. If there is a rule of law or even a regulation that the decision maker must follow, then he or she has no discretion. If the Navigation Section had not followed AFR 55-34 in some significant way, then the government could have been liable for negligent route selection because the action would no longer be discretionary. Flight planning is not automatically discretionary. In Wildwood Mink Farm v. U.S. (1963), two young pilots on a cross country flight flew over a mink farm, allegedly causing the death of some mink. The court found that they had been given no instructions on where to fly and had planned the flight themselves. The court held that this was an action at the operational, not planning, level, and the government was liable for their negligence. Once a function is determined to be discretionary, the government is immune from liability, even if the discretion is negligently exercised or even abused.

Liability for Operations Using Chaff or Flares

The government and its personnel would not be liable under FTCA for deciding to use chaff or flares in the operation of its aircraft in the United States. Selection of places to use them is also immune, as would be times of day, seasons of the year, and altitudes of flight. However, in making these choices, all applicable regulations must be followed. Then, the aircrews must follow the plans. Deviation is likely to be regarded as negligence, even if (as in the Peterson case) the fault lies with instruments, faulty ground directions, or defective flares, rather than with the actions of the crews themselves.

In cases where military aircraft damage private property, the government rarely has direct observers of the incident (other than the aircrew), and the plaintiff typically offers eyewitness evidence that the government cannot counter. Eyewitness evidence is traditionally accepted as valid. In the Peterson case, the Petersons testified that the B-52 was at 75 feet, while the pilot thought he was at 550. Since he lacked instruments, his claim was discounted. A B-52 at low altitude or an F-16 at speed would be hard for the untrained observer to judge. Without an adequate altitude margin, eyewitness testimony about flare use is likely to place the aircraft much lower than it actually was, and lower than the altitude required by Air Force regulation for flare use. Violation of the regulation will be taken as operational negligence, and the government will be liable for any resulting damage.

Duds that ignite after hitting the ground present a different problem. While the route that placed the pilot where he fired his flares is discretionary, flares are supposed to be consumed in the air and not reach the ground. Ample evidence from government files is available to prove this, including the specifications for purchase which prescribe burn times and reliability rates (see Section 5.2). Therefore, if a flare does not ignite in the air, it is likely that the government will be found negligent and pay for any ensuing damage. While the manufacturer might be responsible to the government for the loss, typically this type of liability is not pursued. The damaged party, on the other hand, will probably be unable to sue the manufacturer directly. The Supreme Court recently held that a government contractor who builds a piece of military equipment to government specifications is not liable for any resulting damages. The injured parties must sue the government under FTCA.

3.2.1.2 The Military Claims Act

The Military Claims Act (MCA) (10 USC 2731-2737) provides for prompt payment of claims arising out of non-combat activities of the armed forces. This includes military-unique activities having no direct civilian counterpart, such as maneuvers, practice bombing, and sonic booms (AFM 112-1). The claimant need show only a causal connection between the activity and the injury; negligence is not required. It represents a judgement on the part of Congress that the government should bear the cost of obviously dangerous things military forces do in peacetime, even if the soldiers or airmen involved made no mistakes and were not careless. (Wartime battle damage is not covered.) Claimants may not sue the government under the MCA. Claims for up to $25,000 may be paid in the field; up to $100,000 by the Secretary of the Air Force. Still higher amounts that the Secretary believes should be paid can be sent to the General Accounting Office for consideration under their general claims settling authority. This process avoids the cost and delays of litigation.

Due to the generous provisions of the MCA, most valid damage claims arising from chaff and flares use will result in settlement. Both the size of the claim and the need to show only a causal connection between flare and damage fit within its terms. Since no negligence needs to be proven, whether the plane was at 300 or 550 feet will not be important for this purpose.

3.2.2 Liability for Taking of Property

The Fifth Amendment to the Constitution provides that "private property shall not be taken for public use, without just compensation." The most direct form of taking is purchasing a tract of land so that it becomes government property. This can be done by agreement, or by an action filed in federal court. In court, the government states that it needs the property for public use, and the court sets just compensation (usually fair market value) as the amount to be paid. The owner has the opportunity to demand more money, but except in rare instances cannot effectively block the purchase. This is called condemnation or eminent domain.

However, property can also be "taken" by the government by regulation that destroys its value (regulatory taking) and by physical actions that permanently reduce the value. In U.S. v. Causby (1946), aircraft landing and taking off from Seymour-Johnson AFB (then operated by the Army Air Corps) regularly and frequently passed over Mr. Causby's chicken farm at an altitude of 83 feet. This frightened the chickens and caused them to stop laying. The Supreme Court held that these low and frequent flights, which significantly reduced the value of the property to a potential buyer, were the same as condemning an easement over the property. (An easement is the right to do some actions on the land of another without acquiring ownership, leaving to the owner the right to do anything not inconsistent with the easement.) The Court ordered the Air Corps to pay Mr. Causby for the reduction in value. Mr. Causby was not suing for the value of the unlaid eggs, or for chicken mortality, but for the loss of property value in the farm itself, based on the inference that a buyer would not pay much for a bad chicken farm. If he had sued for property damage (chickens, eggs, etc.), it would have been a routine damage case. In many later cases, the U.S. Court of Claims has actually ordered the landowner to convey a formal easement to the government on payment of the judgement. Claims for "inverse condemnation" (taking interests in property without paying for them) for over $10,000 must be filed in the U.S. Court of Claims under the Tucker Act (28 USC 1491(a)).

In the Air Commerce Act of 1926, Congress declared the sky over 500 feet to be open to public use. As a result, claims for inverse condemnation from flights above that altitude have been held not to be a taking in all but one case, Branning v. U.S. There the Branning property was deliberately chosen as the route for Field Mirror Landing Practice, in which dozens of Marine F-4s would proceed nearly nose to tail for hours at a time at 600 feet — an altitude selected in view of the 500 foot rule. These actions were held to constitute a taking notwithstanding that rule.

It is marginally possible that circumstances could arise in which chaff or flare use, or both, would be held to be a taking of property. Frequent low altitude flights, and probably some unpleasant effects such as smoke, smell, piles of chaff, etc., might significantly diminish a property's appeal to a hypothetical buyer, even if there were no significant physical damage to the land. The resulting loss of market value could lead to liability for taking. If the land were physically damaged, the owner might be able to recover the loss under the FTCA or the MCA. Taking involves loss of land value, not physical damage. The two are separate concepts, and recovery must be obtained under different laws and procedures in different courts.

Taking claims are rarely settled at the military service level, because there is no settlement authority other than purchasing an easement. Congressional limitations on purchase of interests in land usually make that infeasible. Military departments have authority to make minor land acquisitions costing up to $200,000 per tract or group of contiguous tracts (10 USC 2676). This authority has been used to settle claims that would otherwise have been takings, by buying either fee title or easements. Land purchases above that amount require specific statutory authorization and appropriations from Congress. Normally, an owner claiming inverse condemnation must file an action in the Court of Claims, where the Department of Justice can settle it. Payment is from the Judgement Fund of the Treasury in most cases, not from Air Force funds.

Nearly all cases claiming inverse condemnation by reason of low and frequent flights have involved landing and taking off at busy airfields. Chaff and flare use might, as indicated above, be deemed to reduce value of land under a MOA or MTR so much that a court would find a compensable taking. This is not a particularly likely occurrence however, especially if the altitude limits in AFR 55-79 are generally observed.

4.0 CURRENT DATA ON ENVIRONMENTAL EFFECTS OF CHAFF

4.1 ENVIRONMENTAL PATHWAY ANALYSIS

Chaff from ACC training activities has the potential for entering every medium of the environment. Chaff fibers are ejected from aircraft into the air and eventually settle to deposit on land or on water, where they may be further transported. Within each medium, chaff has a potential for raising a number of direct and indirect environmental and safety issues. Figure 4.1-1 presents a graphic depiction of the potential pathways chaff may take in the environment, the various recipients it may affect, and the types of impacts that may result.

The first issue precedes actual deployment and is related to potential safety risks to aircrews from improper or incomplete ejection of the chaff from the aircraft. Some chaff is ejected through the use of a pyrotechnic initiation cartridge. This device generates air emissions with potential air quality impacts. The chaff itself remains suspended in the air for a period of time, raising issues of air quality impacts, safety impacts from unintended interference with FAA and other radar systems, safety risks to other aircraft engines, and impacts on birds and bats. Not all these pathways may present significant risks, but they all need to be addressed in a comprehensive analysis.

The length of time chaff remains airborne, in combination with local meteorological conditions and the altitude of deployment, affects the distance that chaff is likely to drift and the geographic extent of its potential effects. Eventually, the chaff will settle to the earth's surface, where it may be deposited on water or on land.

If the chaff is deposited on water, the potential issues will depend in part on whether the water body is the ocean or an inland water body, and then whether it is an enclosed body (pond or lake) or a running stream or river. The primary areas of concern fall into one of two categories: chemical effects or physical effects. Chemical effects relate to the potential for chaff to cause chemical changes in the water and thereby affect water quality and biota. Physical effects pertain to accumulation of chaff particles and other debris either on the surface or on the bottom. This accumulation raises issues of potential effects on biota, habitat conditions, and aesthetics. If the body of water is a reservoir, issues of impacts on drinking water sources are also raised.

If the chaff is deposited on land, impacts there can also be chemical or physical. Questions about the chemical effects on soil raise issues of potential indirect effects on groundwater, vegetation, and archaeological deposits. Issues concerning chemical effects on wildlife through ingestion, inhalation, or dermal contact are related to the basic toxicity of chaff and its constituent materials. Physical effects to be examined range from impacts on wildlife to impacts on land use and visual resources. If the aesthetics of an area are affected by the accumulation of chaff, this could in turn affect certain types of land use, such as recreation, as well as the context of certain historic resources. Native American values may be indirectly affected by any of the potential direct effects of chaff. Safety issues raised by chaff settling to the ground

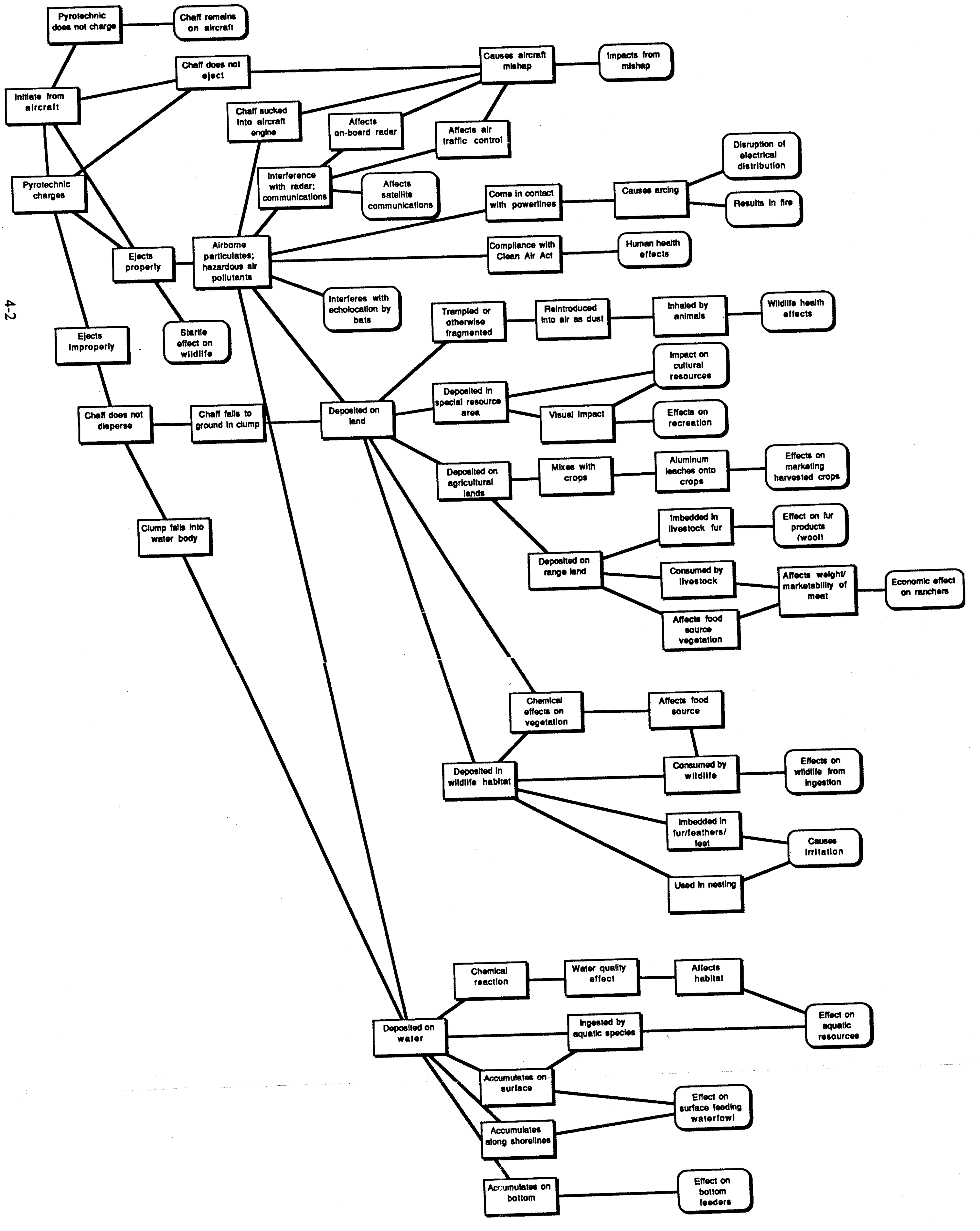


Figure 4.1-1. Chaff Pathways into the Environment

include potential for interference with electrical distribution if a chaff cloud drifts into a powerline and questions of whether falling debris could pose a hazard to people on the ground.

4.2 MATERIAL COMPOSITION AND MANUFACTURE

4.2.1 Chaff Materials and Containers

The principal sources of the data on chaff composition are the Air Logistic Centers at Hill AFB, Utah (for pyrotechnic chaff) and Warner Robbins AFB, Georgia (for non-pyrotechnic chaff). Data sources included published specifications and technical orders, supplemented by a visit to Hill AFB and telephone conversations with Air Force personnel at these centers and with industry representatives from the Tracor Corporation.

There are two types of chaff, aluminum foil and aluminum-coated glass fibers. The foil type is no longer manufactured, although some may remain in the inventory. Both foil and fibers are cut into dipoles ranging in length from 0.3 to 2.0 inches. They are made as small and light as possible so they will remain in the air long enough to confuse enemy radar. The aluminum foil dipoles are 0.35-0.45 mils (0.00035-0.00045 inches) thick and 4 mils wide. The glass fiber dipoles are 1 mil in diameter, including the aluminum coating which is 0.12 $\pm$ 0.06 mils thick. Table 4.2-1 lists the components of the glass fibers and aluminum coating.

Both chaff types have a slip coating to prevent end welding of fibers when cut and to minimize clumping when ejected. It is a 1 percent solution of Neofat 18 (90 percent stearic acid and 10 percent palmitic acid) with naphtha as the solute. The naphtha is driven off during the curing process. The foil chaff has each cut wrapped in a thin paper sleeve. The foil chaff that is contained in cardboard boxes also had a lead-based coating designed to offset the center of gravity of each dipole to increase flutter.

Either type of chaff can be ejected from the aircraft either mechanically or pyrotechnically. Mechanical ejection uses small foil-laminated cardboard boxes (2.8 by 4.8 by 0.8 inches) that are torn open during ejection. Debris from the cardboard boxes consists of the opened box, two high impact polystyrene plastic support pieces (2.75 by 4.75 by 0.06 inches), and paper wrapping for each dipole cut. Cardboard specifications have been changed from virgin kraft paper to recycled kraft paper because it biodegrades more quickly (Frankel, personal communication, 1993). The sealing adhesive for these boxes is an aqueous type polyvinyl acetate.

Pyrotechnic ejection uses two methods. The method for aluminum-coated glass fibers generates hot gases from an explosive cartridge that push a small plastic piston down a chaff-filled tube 8 inches long with a 1 inch square cross-section. This ejects a small plastic end cap, followed by the chaff fibers. The tube remains in the aircraft. Debris that is ejected consists of two 1 inch square pieces of plastic 1/8 inch thick (the piston and the end cap) and a felt spacer. The ejection method for foil uses a small plastic cassette (3.0 by 5.0 by 0.9 inches) that has an internal pyrotechnic train with an initiator and explosive cord that fractures the case after

Table 4.2-1. Components of Glass Fibers and Aluminum Coating

Element	Chemical Symbol	Percent (by weight)
Glass Fiber		
Silicon dioxide	SiO_2	52-56
Alumina	Al_2O_3	12-16
Calcium Oxide and Magnesium Oxide	CaO & MgO	16-25
Boron Oxide	B_2O_3	8-13
Sodium and Potassium Oxide	Na_2O & K_2O	1-4
Iron Oxide	Fe_2O_3	1 or less
Aluminum Coating*:		
Aluminum	Al	99.45 min
Silicon + Iron	Si+Fe	0.55 max
Copper	Cu	0.05
Manganese	Mn	0.05
Magnesium	Mg	0.05
Zinc	Zn	0.05
Vanadium	V	0.05
Titanium	Ti	0.03
Others		0.03
*Aluminum is typically Alloy 1145		

ejection. Debris from the plastic cassette consists of fragments of the cassette, a firing pin spring, a firing pin housing, two ball bearings, a spring pin, an ignitor rod, and kraft dipole wrapping paper.

Explosive impulse cartridges are used to eject pyrotechnic chaff from their cases. Table 4.2-2 summarizes the characteristics of two types of impulse cartridges used for chaff.

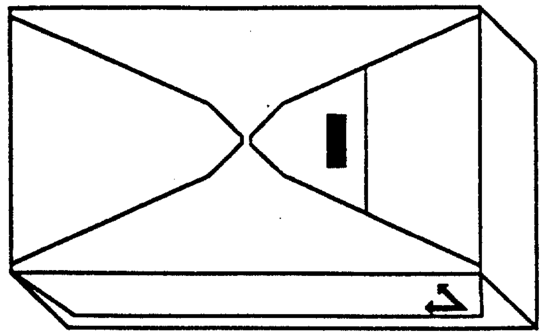
Information obtained from ACC units and ranges indicates they use six varieties of chaff: RR-72, RR-112, RR-129, RR-141, RR-144, and RR-170 (see Table 2.4-1). RR-72 and RR-112 are used exclusively by B-52 aircraft. Both are non-pyrotechnic. The more widely used of the two is the aluminum-foil-laminated kraft paper box, designated RR-112A/AL (Figure 4.2-1). It contains 10 million aluminum-coated glass fiber dipoles in five cuts ranging from 0.3 to 0.6 inches in length. The older unit that contained foil chaff was designated RR-112/AL. The RR-72C/AL unit is the same as RR-112A/AL except for dipole lengths ranging from 0.563 to 2.063 inches in nine cuts.

Table 4.2-2. Impulse Cartridges Used With Chaff Units

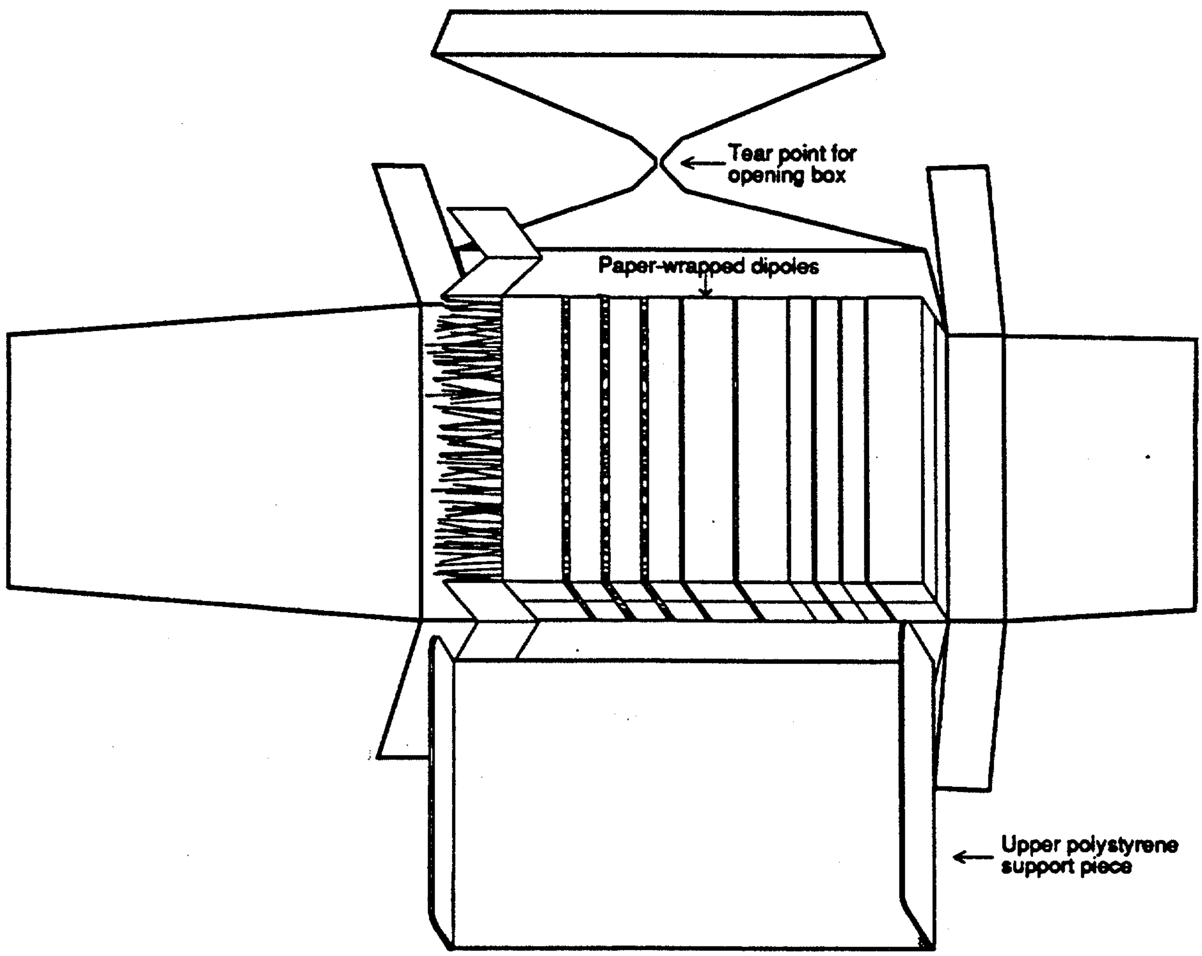
Size	BBU-35/B	BBU-48/B
Overall	.625d × .530 0.163 (in^3)	0.975d × 0.60 0.448 in^3
all explosive	0.034 (in^3)	0.0031 in^3
Initiation	(.356d × .34)/4 0.008 (in^3)	0.14d × 0.085 0.0013 in^3
Booster	(.356d × .34)/4 0.008 (in^3)	---
Main charge	(.356d × .34)/2 0.017 (in^3)	0.14d × 0.12 0.0018 in^3
BRIDGEWIRE	Tophet A 0.0025 dia × .15	
DISC	scribed disc	
INITIATION CHARGE	130 mg 7650 psi boron 20.0% potassium perchlorate 80%	50 mg titanium 30% potassium perchlorate 44% boron nitride 25%
BOOSTER CHARGE	105 mg 7030 psi boron 18.0% potassium nitrate 82.0%	
MAIN CHARGE	250 mg loose fill RDX* pellets 38.2% potassium perchlorate 30.5% boron 3.8% potassium nitrate 15.3% super floss 4.6% viton A 7.6%	50 mg Nitrocellulose 88.7% dinitrotoluene 9.5% diphenylamine 0.9% potassium sulphate 0.9% graphite 0.2%

Source: Air Logistics Center, Hill AFB, UT, and IMR Powder Company, Plattsburgh, NY

*RDX is cyclotrimethylenetrinitramine (1, 3, 5-trinitro-hexa-hydro-s-triazine)



CLOSED BOX



OPEN BOX

Figure 4.2-1 Non-Pyrotechnic Chaff

RR-129 and RR-144 are used by the Navy. Information on their composition was requested from Navy sources, but it was identified as classified.

RR-141D/AL is the plastic cartridge type of pyrotechnic chaff (Figure 4.2-2). It contains 11 cuts, each wrapped in kraft paper sleeves, totaling approximately 2.76 million dipoles. This unit, the only foil pyrotechnic chaff remaining in the inventory, is used only by F-111 aircraft. Less than 1,000 units per year are used. The F-111 is being converted to use RR-170A/AL (Schirack, personal communication, 1992).

The most widely-used pyrotechnic chaff is the tubular type, RR-170A/AL, containing approximately three million dipoles (Figure 4.2-3). It uses the BBU-35/B impulse cartridge (Figure 4.2-4). Approximately 2 million units per year are used by A-7, A-10, F-16, and C-130 aircraft; one-half of these are used by ACC (Bodner, personal communication, 1993). (Data received from ACC units only confirm about half this amount.) Future procurements will substitute the RR-188 for training operations. It has the D and E band dipoles removed to avoid interference with FAA radars.

A new variety of chaff, RR-180/AL, is currently in the experimental stage. Its case has the same external dimensions as the RR-170A/AL. The interior space is divided into two longitudinal compartments that can be fired separately using a BBU-48/B dual impulse cartridge. Each compartment has a piston and end cap about half the size of those used in the RR-170A/AL. The fibers are sightly smaller in diameter (0.7 mil vs. 1 mil), permitting the unit to hold a total of 5.4 million dipoles. The RR-180/AL is not yet in the inventory.

Another experimental unit, RR-185/AL, also not yet in production, is being developed to replace the cardboard containers of non-pyrotechnic chaff with a plastic box split along the longitudinal edge. It would be held together with metal clips that would be removed as the unit leaves the aircraft. Plastic is being substituted for paper to avoid problems of moisture absorption when the containers are stored for long periods. When taken to high altitudes or in cold ambient conditions, the moisture in paper containers freezes, and the boxes will not open. The aluminum foil laminated paper boxes and their polystyrene support pieces would be replaced by plastic boxes in the RR-185/AL model. The metal clips would be added to the debris.

Chaff units are tested to ensure their ability to withstand any combination of environmental conditions listed in Table 4.2-3 that might be encountered during storage, shipment, and operation. After a prescribed sequence of tests, the units must demonstrate ejection of 98 percent of the chaff in undamaged condition, with a reliability of 95 percent at a 95 percent confidence level.

4.2.2 Toxicity of Chaff

Based on reviews of numerous toxicological studies, the key components of chaff (aluminum, silica glass fibers, and stearic acid) will not pose an adverse impact to human and environmental health. The components of the chaff are likely to have insignificant effects on humans and the

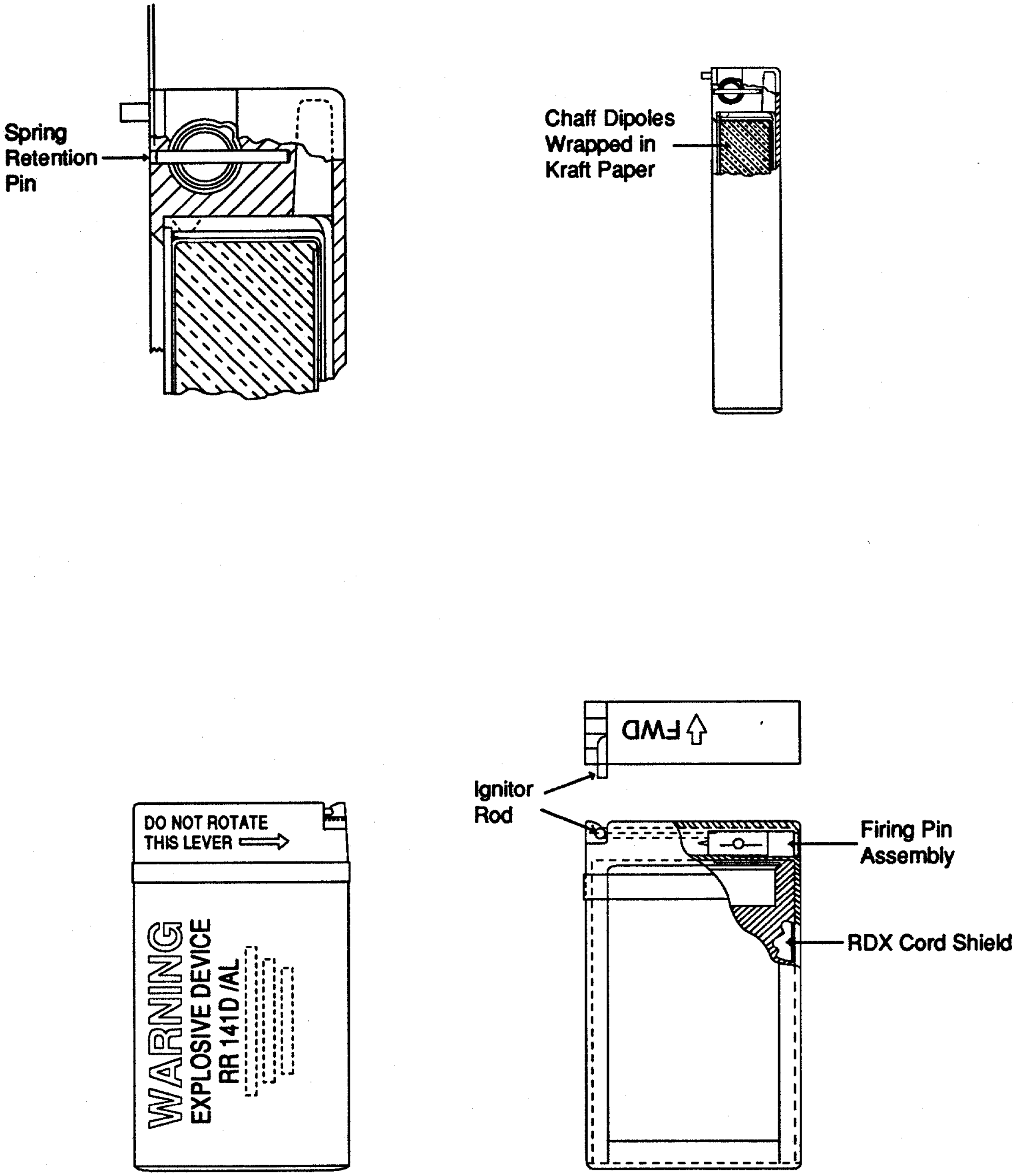


Figure 4.2-2 Chaff Assembly, RR-141D/AL

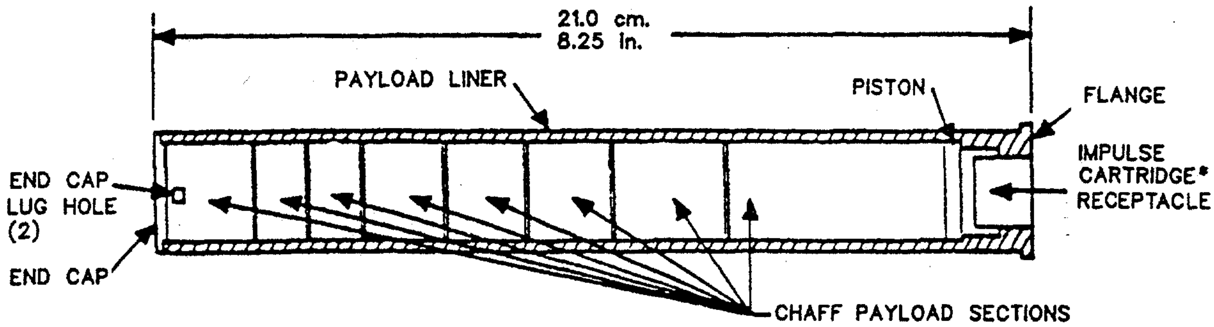


Figure 4.2-3 Cartridge Chaff CM RR-170A/AL

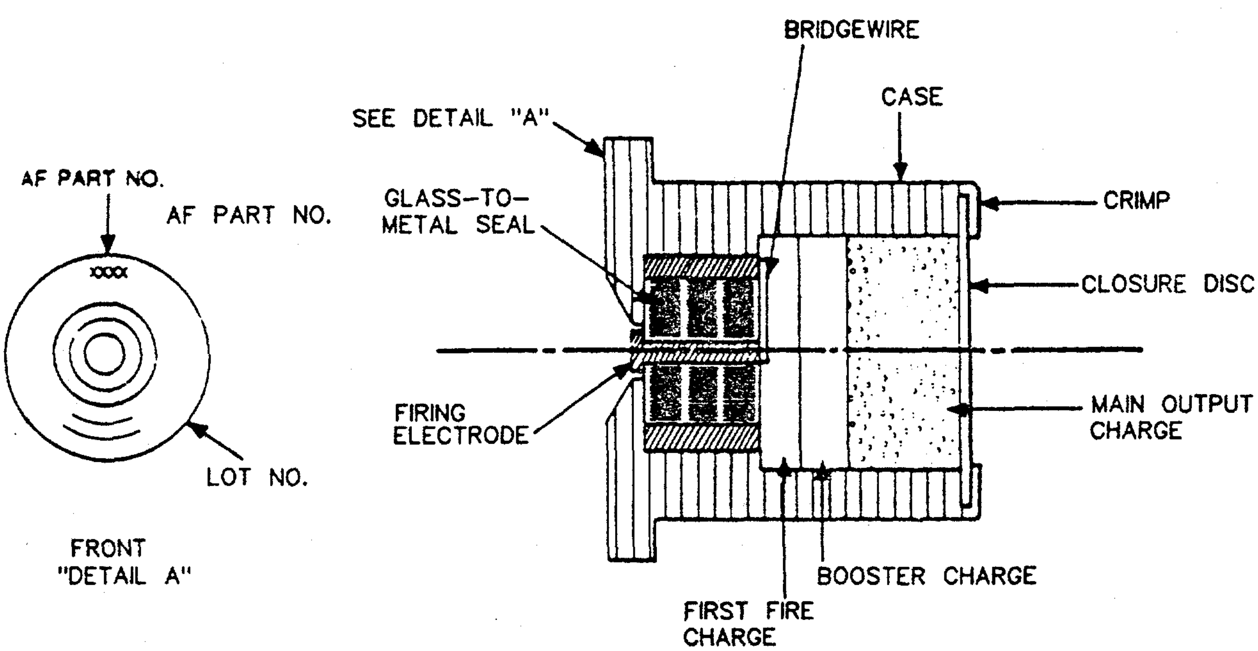


Figure 4.2-4 Cartridge, Impulse, BBU-35/B

Table 4.2-3. Environmental Conditions for Chaff Testing

Environment	Requirement	
High Temperature	Up to +165° F	
Low Temperature	Down to -65° F	
Temperature Shock	Shock from -70° F to +165° F	
Temperature Altitude	Combined temperature altitude conditions up to 70,000 feet	
Humidity	Up to 95 percent relative humidity	
Fungus	Fungi encountered in the tropics and subtropics	
Salt Fog	Salt fog encountered in coastal regions, sea locations and during ocean transportation	
Sand and Dust	Sand and dust encountered in desert regions subject to high sand dust conditions and blowing sand and dust particles	
Acceleration/Axis	G-Level	Time (Min.)
Transverse-Left (X)	9.0	1
Transverse-Right (-X)	3.0	1
Transverse (Z)	4.5	1
Transverse (-Z)	13.5	1
Lateral-Aft (-Y)	6.0	1
Lateral-Forward (Y)	6.0	1
Shock (Transmit)	Shock encountered during aircraft flight	
Vibration	Vibration encountered during aircraft flight	
Free Fall Drop	Shock encountered during unpackaged item drop	
Vibration (Repetitive)	Vibration encountered during rough handling of packaged item	
Three Foot Drop	Shock encountered during rough handling of packaged item	

environment based upon the general toxicity of the elements, the dispersions patterns, and the propensity of the element to synergize with other substances in nature.

Previous documents on chaff (SEA 1989 and 1990) have used the words "glass" and "fiberglass" interchangeably in describing chaff. Chaff is composed of aluminum coated glass fibers, which are different from fiberglass. The use of the term fiberglass is incorrect and could lead to an inaccurate interpretation of the materials of composition and its resultant toxicological effects. The more precise terminology is aluminum coated glass fibers.

The primary source of the toxicological information presented in this section is TOMES which comprises twelve different databases, including the Hazardous Substances Data Bank (HSDB), Registry of Toxic Effects of Chemical Substances (RTEC), Oil and Hazardous Materials/ Technical Assistance Data System (OHM/TDS) and Integrated Risk Information System (IRIS). The TOMES database is managed by EPA.

One of the primary ingredients in the composition of chaff is aluminum metal. Potential exposure to aluminum from chaff may occur by either ingestion or inhalation. Aluminum is one of the most abundant metals in the earth's crust and is ubiquitous in soil, water, and air. In general, research has shown aluminum is relatively nontoxic unless acute exposure occurs at high doses or chronic exposure occurs over time. Aluminum compounds are often found as food additives, such as in baking soda and antacids. In addition, aluminum compounds such as aluminum sulfate are used in the treatment of potable water. Studies on the effects of inhalation of aluminum dust are primarily related to chronic occupational exposure data. Chronic exposure to aluminum as a result of inhalation of bauxite (Al_2O_3-$3H_2O$) fumes has provided evidence of links to development of pulmonary fibrosis (Casarett and Doull 1986). Chronic occupational exposure studies do not accurately reflect environmental conditions, however. The amount of actual aluminum exposure from chaff will be difficult to predict. Chaff use is highly unlikely to approximate chronic occupational levels or durations for aluminum.

The aluminum alloy used on chaff contains small quantities (< 1% each) of residual elements that include silicon, zinc, and iron. Silicon, zinc, and iron react minimally with environmental conditions and are found freely in nature, with the exception of silicon, which is found in the form of silica. These compounds are virtually insoluble in water and their presence in air is negligible. Exposure to humans and animals is primarily via ingestion of foods contaminated with these elements. In general, studies reveal that acute exposures to silicon may result in mild eye irritation but otherwise do not contribute significantly to toxicity (Sittig 1985). Both zinc and iron are nutritionally essential metals. Deficiencies of either metal can contribute to a wide spectrum of clinical effects depending on the age and stage of development of an individual. However, excessive chronic exposures of each metal can also contribute to excess body burden over a period of time. High concentrations of these metals can produce acute effects in a number of species; however, the trace amounts of each element present in chaff are minimal, and the likelihood of contributing to environmental toxicity is insignificant.

The primary component of the glass fibers in chaff is silicon dioxide. This is an abundant compound in nature that is prevalent in soils, rocks, and sand. Insufficient data are currently available to evaluate additional environmental fate. However, due to its natural prevalence in the environment, it may be speculated as not inductive of environmental stress. No data on potential adverse effects of ingestion of silicon oxide is currently available. The majority of findings on exposure to silicon compounds is from chronic occupational exposure studies. Chronic occupational inhalation exposure studies have shown individuals to develop silicosis, but further studies conclude that silicosis may result from exposure to crystalline forms of silica (Casarett and Doull 1986). Numerous toxicity data on silica are available; however, specific data on silicon dioxide is limited. Toxicity data on generic glass fibers show that the fibers are biologically inert (SAIC 1989).

Additional elements present in the glass fibers include aluminum oxide, calcium oxide, magnesium oxide, boron oxide, sodium oxide, potassium oxide, and ferric oxide. Each of these chemicals independently exerts toxic effects through different routes of exposure. For example, both B_2O_3 and CaO exert toxicity primarily through ingestion (CaO is also a skin irritant), whereas toxicity studies on Fe_2O_3 show it to be linked to adverse health effects through inhalation route. Furthermore, these chemicals independently pose a toxic effect either acutely or chronically. For example, CaO, more commonly known as lye, can produce acute toxic effects upon ingestion of high doses, but minimal quantities of this compound are used as supplemental food additives. Several occupational exposure studies have shown ferric oxide to be linked to lung cancer (HSDB 1993(a)). Occupational exposure studies cannot accurately reflect what will happen in environmental settings since occupational concentrations and exposure durations are much higher and longer than what would be expected in non-occupational settings. A number of studies have shown that many of the above mentioned chemicals have produced toxicity in wildlife; however, most of these tests were in a laboratory setting with prescribed doses and controlled environments. How a species tolerates chemical exposure in a laboratory setting versus the natural environment is difficult to correlate. The chemical additives in the glass fibers are fused together in a stable state, and it is unknown whether they will break down to their independent forms or react chemically with other environmental substances. Even if the fibers are not stable in the environment, the chemicals individually make up a small percentage of the fibers, and it can be hypothesized that they do not contribute to environmental toxicity.

Stearic acid is used as a coating agent to bond the chaff components. Toxicity and environmental fate data on stearic acid reveal that the chemical is essentially nontoxic (HSDB 1993(b)). Stearic acid is naturally found as a glyceride in animal fat and in some vegetable oils. The chemical is virtually insoluble in water but can readily be solubilized by various types of chemical compounds including alcohols. The acid has been shown to easily degrade through bacteriological processes. Stearic acid lacks the propensity to penetrate skin or mucous membranes, and data on inhalation exposure is limited. Stearic acid is considered an irritant, but due to its lack of solubility capabilities, its ability to biodegrade, and the minimal quantity found in chaff, it may be surmised that this will not pose a significant hazardous situation. Potential exposure to wildlife may primarily occur through ingestion; however, the quantities required to produce toxic effects is relatively high for most species. Literature review reveals that probable lethal oral dose (LD) for humans would be consumption of more than 2.2 pounds of stearic acid at any one time by an individual weighing 150 pounds (HSDB 1993(b)). A bundle of chaff weighs about 3.4 to 4.4 ounces. A rough estimate of the amount of stearic acid is about 10 grams. Based on that estimate, it would require the consumption of the coating from almost 100 bundles of chaff to achieve a lethal dose of stearic acid.

The chaff is containerized using polystyrene support pieces. The polystyrene molecule is a composition of styrene polymers. Polystyrene is a plastic which has excellent insulating properties. Fragments of the support pieces will not pose notable inhalation or dermal exposure; however, exposure may occur via ingestion. Inadequate data are currently available to verify whether styrene polymers are carcinogenic to either humans and animals or to evaluate the metabolism process and environmental fate of polystyrene. However, it is extremely unlikely that humans would have an opportunity to ingest this debris, and animals are unlikely to selectively consume it while foraging.

In summary, the data indicate that the materials comprising the chaff dipoles are generally non-toxic in the quantities present. There is no realistic worst-case scenario under which sufficient quantities would be present in the environmental to pose a health risk.

Older productions of foil chaff reportedly contained lead. It is not known whether any of this chaff still exists in inventory. Lead is known to be toxic and can lead to a number of health problems.

Another potential health concern with chaff use is the release of air toxics during detonation of the impulse charge. A complete toxicological analysis could not be completed since there was insufficient information related to the detonation products. Nonetheless, current information indicates that chromium (III and VI) substances could be released during detonation of older chaff inventories. Calcium chromate has been replaced by potassium perchlorate in the BBU-35/B initiator, so currently produced chaff would not have chromium products. The toxicological properties of chromium and lead are described in Appendix E.

4.2.3 Effects of Chaff on Electromagnetic Radiation

Chaff is designed to interfere with radar in the 2-18 Gigahertz (GHz) range. This range is also used for various communication devices, including earth-to-space links. Since chaff is designed to re-radiate an incoming signal, it would not distort communications between a transmitter and receiver because the fades and gains in the signal would cancel each other. Therefore, chaff would not affect radio frequency transmissions, including radio, TV, and radio communications.

As noted in Section 2.5.1, however, chaff interferes with all types of radar, including:

- Satellite tracking
- Weather radar
- Airborne radar, including weather
- Marine radar, both civil and military

- Collision avoidance radar
- Radar altimeters
- Terrain avoidance radar
- Air traffic control radar

Satellite tracking could be interrupted for a long enough period for the objects to be lost temporarily (although it could be reacquired, if the orbital parameters are known). Chaff could possibly create a false return on some weather radars. Detection by collision avoidance radars (although highly unlikely), might also induce unintended avoidance maneuvers.

4.3 SAFETY

Chaff is used by ACC aircraft to confuse or mislead radar-guided anti-aircraft systems. Its effective use in combat requires realistic training. The use of chaff may cause infrequent but predictable mishaps and accidents that may result in impacts on people and the environment. This section identifies potential mishaps associated with the use of chaff, describes the information sources regarding these mishaps, identifies data gaps in the mishap information, and analyzes initial consequences of expected mishaps.

4.3.1 Safety Issues Pertaining to Chaff Use

Because of its physical composition, inappropriately or inadvertently deployed chaff can produce undesirable results. The effects of inappropriate or inadvertent chaff deployment on humans and natural resources are discussed in Sections 4.4 through 4.8. This section focuses on the safety issues of the chaff deployment system. The safety events of concern (issues) include the following:

- Disruption of FAA or other radars.
- Interference with satellite communication.
- Disruption of electrical distribution systems.
- Damage to aircraft from ingestion of chaff.
- Damage to aircraft from chaff system malfunctions.
- Injury to ground crews from a system malfunction.

- Distraction of pilots due to chaff deployment.

- Injury from falling chaff debris.

4.3.2 Summary of Existing Literature/Information

The effects of chaff have been evaluated in various studies and reports dating back to 1952. A wide range of sources were accessed and evaluated for applicable information for this review, including DIALOG databases listed in Appendix B. Non-DOD sources have not been contacted. While a number of reports and studies exist, no formal safety analyses of the chaff system (Safety Analysis Review [SAR] or Probabilistic Risk Assessment [PRA]) could be found in any of the sources.

The most comprehensive data concerning mishaps were received from Headquarters Air Force Safety Agency, the Air Force Directorate of Nuclear Surety, and Headquarters Air Combat Command Explosives Safety Section. The Headquarters Air Force Safety Agency, prior to implementing a new computer database program on March 1, 1993, maintained mishap data for 17 years. Under the new system, data are only maintained for 10 years. Some pre-1983 data are available and will be referenced.

Air Force mishap categories and classes are defined in AFR 127-4, Investigating and Reporting U.S. Air Force Mishaps. Relevant excepts from AFR 127-4 are provided in Appendix F. Air Force mishap categories are:

- Class A Mishap. A mishap resulting in a total cost of $1 million or more for property damage; a fatality or permanent total disability; or destruction of or damage beyond economical repair to an Air Force aircraft.

- Class B Mishap. A mishap resulting in a total cost of $200,000 or more, but less than $1 million for property damage; a permanent disability; or hospitalization of five or more personnel.

- Class C Mishap. A mishap resulting in a total damage that costs $10,000 or more, but less that $200,000; an injury or occupational illness that results in days away from work (8 hours or greater); or a mishap that does not meet the criteria above, but which AFR 127-4, Chapters 5-9 requires reporting.

- Class D Mishap. A mishap resulting in a total damage that costs $2,000 or more, but less than $10,000; a lost workday case involving more than 1 but less than 8 hours; a nonfatal case without lost workdays; or a mishap that does not meet the criteria above, but which AFR 127-4, Chapters 5-9 require reporting.

- High Accident Potential. Air Force system events that have a potential for causing injury, occupational illness, or damage if they should recur. These events may or may not have reportable mishap costs.

4.3.2.1 Historic Mishaps

From January 1983 to February 1993 there were no Class A, B, or C Explosive Mishap (not involving aircraft) category incidents involving chaff. There were five Class D and 42 High Accident Potential mishaps (Table 4.3-1). These incidents occurred primarily during removal of chaff from or return to storage, routine maintenance, or bench testing/troubleshooting of system malfunctions. However, these mishaps did not occur during flight operations and did not impact the natural environment.

During flight operations from January 1983 to February 1993, there were no Flight or Flight-Related Aircraft Mishaps involving Class A, B, or C mishaps. The Class D mishap class is not used in conjunction with aircraft categories. There were 53 chaff-related High Accident Potential mishaps in the Aircraft Involvement category (Table 4.3-2). These incidents resulted in no fatalities or permanent physical disability. The amount of damage was greater than $2,000 but less than $10,000.

Table 4.3-1. Chaff Non-Aircraft Mishaps, 1983-93

Class	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
D								4	1		
Other*	3	5	15	10	5	4					

*High Accident Potential

Table 4.3-2. Chaff (Aircraft Involvement) Mishaps, 1983-93

Class	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Other*	4	4	15	14	6	3	1	5	1		

*High Accident Potential

Deployment system errors that can cause inadvertent release of chaff include electrical system malfunctions, technician error, and mechanical system wear and tear. During 1985-86, a mechanical problem with the AN/ALE-40 Chaff/Flare Dispensing system was encountered, accounting for the higher incidence of inadvertent releases of chaff packages. A modification to the system was implemented fleet-wide in 1987 that corrected the problem.

From January 1976 to February 1993 there were no reported Missile Mishap category accidents or incidents involving chaff packages used on Minuteman II, Minuteman III, and Peacekeeper Ballistic Missile weapons systems. However, 16 deficiencies (DULL SWORDS) were reported. The two main causes were listed as "fair wear and tear" and "material failure." No DULL SWORD deficiency resulted in a personnel injury or equipment damage.

Chaff use in training exercises has affected civilian FAA radar systems. There are two recorded incidents of FAA radar interference; the first in California involving a Navy fighter, and the second in Arizona involving two Air Force F-16 aircraft. Detailed accounts of these occurrences have been requested but not yet received.

4.3.2.2 Air Force Safety Analysis Methodology

Air Force System Safety evaluations are based on hazard severity categories and the probability of occurrence. Hazard Severity Categories and the corresponding AFR 127-4 mishap classes are described in Table 4.3-3. Hazard probability categories and the assumed annual frequencies are described in Table 4.3-4. A safety evaluation categorizes each mishap event into its appropriate severity and probability categories and develops an alpha-numeric designation, a Hazard Risk Index (HRI), for each group of events.

The HRI, illustrated in Table 4.3-5, enables a hazard to be ranked by its alpha-numeric value and compared with other hazards or hazardous conditions. HRI values of category 3D or greater generally result in an Air Force action to correct the hazard or hazardous condition or to reduce the hazard (HRI value) to an acceptable level. Hazard Risk Required Action, Table 4.3-6, indicates actions required, prioritized according to severity based on the HRI value.

Based on the available historic data, aircraft related and non-aircraft related mishaps involving chaff were evaluated using the severity and probability categories described above. Table 4.3-7 summarizes the Air Force-wide chaff mishap data from 1983 to 1992 under this system.

4.3.2.3 Chaff System Safety Risks

Potential safety issues related to chaff use have been grouped into a reasonable set of events and evaluated based on the Air Force Safety Analysis methodology. Other mishaps, which are more speculative and would require many low-probability, independent events to occur are not included in this safety evaluation. The events of concern are those with historic or postulated safety effects. These events and their expected results (based on historic data, where available) are described in Table 4.3-8. Based on the Air Force experience with chaff systems, as reflected in the data obtained to date, the expected frequency of occurrence of each of the events and results are listed in Table 4.3-9.

4.3.2.4 Consequences of System Safety Events

Chaff has been reported to stay aloft for relatively long periods (potentially up to 1.5 hours [SEA 1989], or 10 to 12 hours [Eglin AFB 1973]). Event A would occur if, as a result of the

Table 4.3-3. Hazard Severity Categories

Category	Severity	Results	Mishap Class
1	Catastrophic	May cause death or system loss.	A
2	Critical	May cause severe injury, severe occupational illness, or major system damage.	B
3	Marginal	May cause minor injury, minor occupational illness, or minor system damage.	C D
4	Negligible	May result in less than minor injury, occupational illness, or system damage.	High Accident Potential

Table 4.3-4. Hazard Probability

Hazard Level	Frequency of Occurrence	Probability of Occurrence	Assumed Frequency per Year
A	Frequent	Likely to occur frequently.	>1
B	Probable	Will occur several times in life of an item.	1
C	Occasional	Likely to occur sometime in the life of an item.	10^{-2}
D	Remote	Unlikely but possible to occur in life of an item.	10^{-4}
E	Improbable	So unlikely, it can be assumed occurrence may not be experience.	10^{-6}

Table 4.3-5. Hazard Risk Index

Frequency of Occurrence	Hazard Categories (MIL-STD-882B)			
	(1) Catastrophic	(2) Critical	(3) Marginal	(4) Negligible
(A) Frequent	1A	2A	3A	4A
(B) Probable	1B	2B	3B	3B
(C) Occasional	1C	2C	3C	4C
(D) Remote	1D	2D	3D	4D
(E) Improbable	1E	2E	3E	4E

Table 4.3-6. Hazard Risk Required Action

Hazard Risk Index	Action Required
1A 1B 1C 2A 2B 3A	Unacceptable - Immediate corrective action required.
1D 2C 2D 3B 3C 3D	Undesirable - Reduced priority, correction action required.
1E 2E 3E 4A 4B	Acceptable - Low priority for corrective action. (May not warrant action.)
4C 4D 4E	Acceptable - Correction action not required.

Table 4.3-7. Summary of Historic Mishaps Involving Chaff

Events/Severity (Mishap Class)	Probability [(1)] (Hazard level)	
	Non-Aircraft	Aircraft
1 Catastrophic (A)	0 (E)	0 (E)
2 Critical (B)	0 (E)	0 (E)
3 Marginal (C)	5×10^{-7} (E)	0 (E)
4 Negligible (High Accident Potential)	6×10^{-6} (D)	7.7×10^{-6} (D)

(1)Based on estimated annual ACC use of 660,000 chaff bundles/year reflected on Table 2.4-1.

Table 4.3-8. Chaff System Safety Events

Event	Description	Results
A	Chaff drifts outside of intended airspace	1) Clutters FAA radars 2) Clutters airborne (collision avoidance) radars 3) Interferes with satellite communication
B	Dipoles contact high voltage power line	Disrupts electrical distribution
C	Aircraft ingest chaff	Loss of power, engine shut-down
D	Hung chaff bundle or chaff system malfunctions	1) Injury of ground crew 2) Damage to aircraft
E	Pilots distracted by chaff deployment	Pilot initiates avoidance maneuver
F	Falling debris hits person on ground	Injury from impact

Table 4.3-9. Chaff Event Frequencies

Event	Result	Frequency (per use)
A	1 2 3	1/350,000 1/700,000 1/700,000
B		1/3,500,000
C		1/7,000,000
D	1 2	1/130,000 1/7,000,000
E		1,700,000
F		Unknown
Note: Based on estimated annual ACC use of approximately 660,000 chaff bundles/year reflected in Table 2.4-1.		

deployment of chaff at a high altitude, chaff remains undispersed and drifts outside of intended airspace (or is inadvertently released in an unauthorized area). This could produce radar reflection (noise) in FAA-controlled airspace. This would tend to interfere with air traffic control because of "clutter" of FAA radars (result 1) and could adversely affect the performance of onboard (collision avoidance) radars. Chaff could cause onboard radars to identify "ghost" aircraft and falsely alert pilots to nearby traffic (result 2).

There are records of result A(1) occurring, but there is no official documentation of these events. The Air Force is in the process of switching the physical composition of chaff to eliminate interference with affected FAA radar frequencies. For this analysis, it is assumed that this event has occurred less than two times per year. Since onboard radars would require a more compact distribution of chaff to falsely identify a nearby aircraft, a frequency of less than one per year is postulated for this analysis.

If a chaff bundle were deployed near an active satellite ground station, it could interfere with radio communications between that station and orbiting spacecraft. There are no reported events of this nature. For this analysis, it is assumed that such an event would occur less than once per year.

Chaff dipoles have made contact with high voltage power lines, apparently resulting in a disruption of electrical service. This event has been verbally identified to have occurred twice. For the purposes of this analysis, these two occurrences have been distributed over the same 10-year period associated with the other hazard/accident data.

An aircraft flying closely behind another aircraft that deployed chaff could ingest dipoles into the engine intake. Depending on the type of aircraft and amount of chaff ingested, the engine could loose power or shut down completely. An engine shut-down is an aircraft emergency for which pilots are trained. Since this event has not been reported in the 10 most recent years of chaff use, it has been assigned a frequency of once in this period.

The chaff deployment system has an "aircraft involved" mishap rate described in Table 4.3-2. Hung chaff bundles or chaff system malfunctions occur approximately five times per year. Permanent injury of ground crew or significant damage to aircraft has not been reported over the last 10 years of Air Force operations.

Distraction of pilots by chaff deployment causing the pilots to initiate avoidance maneuvers, has not resulted in a reported mishap by either the Air Force or civilian pilots. For this analysis, this incident is assumed to have a frequency of less than once per year.

The probability of a chaff debris component (other than the chaff itself, which would not cause injury) hitting a person depends on a number of situations — specific conditions (frequency of chaff deployments, density of people underneath deployment airspace) and cannot be estimated generically. The likelihood of injury is negligible, however, given the weight of this debris (about 0.45 oz. for a plastic piston and 0.15 oz. for an endcap), other debris, including kraft paper boxes, create so much drag in comparison to their weight, that no injury would be expected.

By combining the historic mishap probability information from Table 4.3-7 with the postulated events described, hazard evaluations for the events of concern have been developed and are listed in Table 4.3-10. Based on these classifications, all events are within the Acceptable range.

4.3.3 Data Gaps and Unresolved Issues

While a number of studies and reports have been undertaken over the last 40 years, none were designed to reach a definitive conclusion on the issues raised in section 4.3.1. Each addresses a specific, short-term effect of the potential and probable safety impacts of chaff use on the human or natural environment.

It is possible that some potential safety events have occurred but were not reported and would therefore not show up in the historic data. Other events either have not occurred or do not fit into reportable categories. Assumptions have had to be made for this analysis. These assumptions should be validated if possible or tested through additional modeling. Also, the data collected for this analysis were limited to DOD sources. Other sources, such as FAA and land managers of areas underlying special use airspace, were not consulted.

4.3.4 Conclusions and Recommendations

The data reviewed thus far indicate that, over the years, chaff has posed little threat to safety. The existing data indicate that the use of chaff has no history of important safety effects that

Table 4.3-10. Expected Hazard Evaluation of Flare Events of Concern

Event	Severity Index	Probability Index	Hazard Risk Index	Rating/Action Required
A(1)	4	E	4 E	Acceptable
A(2)	4	E	4 E	Acceptable
A(3)	4	E	4 E	Acceptable
B	4	E	4 E	Acceptable
C	4	E	4 E	Acceptable
D(1)	4	E	4 E	Acceptable
D(2)	4	E	4 E	Acceptable
E	4	E	4 E	Acceptable
F	4	D	4 D	Acceptable

cannot be mitigated through the use of existing operational guidelines. The mishap data shows that relatively few, mostly minor, accidents have occurred over the last 17 years. When mishaps did occur, they were confined mainly to Air Force personnel and property. Impacts on civilians were minimal. The extremely rare impacts to FAA radar systems are being mitigated by the change in dipole physical properties.

Based on these data, the probability of certain safety events have been postulated. These conclusions should be validated through additional consultations with FAA and other agencies (e.g., WAPA) who might have data on historical events involving chaff.

4.4 AIR QUALITY

4.4.1 Issues Pertaining to Chaff Use

The issues pertaining to chaff effects on air quality include:

- Compliance with the NAAQS.
- Potential for toxic air emissions regulated under Title III of the Clean Air Act.
- Potential for impairment of visibility in PSD Class I areas.

The Air Force currently uses two types of chaff dispensers: pyrotechnic dispensers, which use hot gasses generated from exploding charges to expel the chaff, and non-pyrotechnic dispensers which use high pressure to expel the chaff. Consequently, for the pyrotechnic chaff, air quality and health impacts could occur from both the chaff material and the explosive charges, while for the non-pyrotechnic chaff, impacts could arise only from the chaff material.

To assess compliance with the NAAQS, it is necessary to evaluate whether suspended particulates and/or respirable particulates are generated or released from chaff usage. Although lead is no longer used in the manufacture of chaff, there may still be some chaff with lead in the inventory. The lead content and the potential for lead emissions must be assessed since lead is regulated under the NAAQS and has been used in the past as part of the strip coating on certain kinds of chaff.

Recently, increased attention has been given to health risks from exposure to toxic air pollutants. Title III of the Clean Air Act sets a mandate requiring the EPA to regulate the emissions of 189 listed hazardous air pollutants. Thus, it is necessary to assess whether any components of chaff and/or those released from explosive charges are considered hazardous air pollutants and thus may cause adverse health effects.

Dispersed chaff can produce a spherical cloud approximately 300 to 600 feet in diameter at a density of one dipole per three to seven cubic feet (SEA 1989). The potential for short-term visibility impairment for chaff usage merits consideration, particularly at PSD Class I areas.

4.4.2 Summary of Existing Literature/Information

4.4.2.1 Review of Past Studies

The primary literature addressing dispersion of chaff and air quality effects is the environmental studies conducted by Science & Engineering Associates, Inc., for Strategic Air Command and the National Guard Bureau (SEA 1989 and 1990). These efforts concentrated on evaluating air dispersion and settling effects of chaff. The 1989 SEA document reports that silica glass fibers for RR-112 chaff have a total diameter of 1 millimeter (0.03937 inches). This diameter differs from current information presented in Section 4.2 which lists aluminum coated glass fiber dipole diameters ranging from 0.001 inches (for typical chaff) to 0.0007 inches (for the superfine chaff). It appears the SEA study confused "mil" (one thousandth of an inch) with millimeter (one thousandths of a meter). Chaff dipole diameter is significant in the air quality impact analysis due to the possibility of dust formation resulting in respirable particulates, a regulated criteria pollutant under the Clean Air Act. Chaff particulate mass is also dependent on chaff diameters when predicting dispersion of chaff to calculate ground level concentrations.

Both SEA documents assert that manufacture of aluminum foil type chaff has been discontinued, it is no longer shipped to the military services and all of the chaff in use is aluminum coated glass fiber dipoles. However, current available information indicates that two foil dispensers, RR-141 and RR-136, are still in the inventory and being used to deploy aluminum foil chaff. The compositions of aluminum foil chaff presented in the 1989 SEA document differs from currently available information for foil type chaff. It is assumed the current data are accurate. Chaff descriptions included in the 1990 SEA document refer to types of chaff varying from 1 to 4 inches in length depending on the frequencies of radar signals against which they will be used (SEA 1990). Recent data indicate that chaff lengths range from 0.3 inches to 2 inches (Section 4.2). These cut lengths are believed to be typical for both pyrotechnic and non-pyrotechnic types of chaff.

The SEA documents reference a technique developed by the Applied Technology Division of Tracor, Inc., to evaluate the dispersion of chaff based upon chaff diameter and atmospheric conditions. Chaff settling profiles and chaff cloud dispersion profiles (charts) included in the 1976 Tracor article were used by SEA to estimate ground-level dispersion. This use of dispersion modeling has limited application since it relates to a single event. Given the random nature of training flights in special use airspace, it is probably not feasible to predict the long-term accumulation of chaff at ground level using dispersion modeling. Dispersion can be important, however, in predicting short-term concentrations of emissions for comparison with air quality standards.

The Tracor charts correlate dispersion to chaff diameter, coating thickness, release altitude, and wind speed. However, they do not account for the aircraft airspeed, which is also a factor that will impact chaff dispersion. The Tracor article also bases all of the curves on 1 mil and 0.5 mil diameter dipoles (0.001 and 0.0005 inch diameter, respectively). No consideration is given to the variation in chaff length. The report indicates that the descent rate of chaff is primarily a function of coating thickness. However, chaff cloud formation and dispersion will be based on chaff mass, which is a function of coated chaff diameter and length, rather than just the coating thickness and chaff diameter.

From a dispersion modeling standpoint, the curves presented in the Tracor article have a very limited application. Utilization of most of the curves is restricted by the narrow range of altitudes (500 feet or less). Only one curve details representative high altitude (up to 10,000 feet) for 1 mil aluminum coated glass chaff. All the curves depend on either the 1 or 0.5 mil core diameter, and there is no mention of chaff length, which prohibits universal use of the data. Since other diameters and coating thicknesses are currently manufactured, the curves may not be applicable. The Tracor charts do not include any data for the superfine chaff and the foil type chaff, which are expected to have different dispersion patterns from the 1 mil chaff.

Using the data presented in the Tracor article, the 1989 SEA document includes one sample estimation of the ground-level dispersion patterns from a single chaff release. Although the document states that the example is based on a 1 millimeter glass core, since they used the Tracor charts, it is actually based a 1 mil diameter, which corresponds to 0.0254 millimeter diameter.

Verification of the curves presented in the Tracor document was not possible because none of the calculations used to generate the curves were given. However, the curves can be evaluated based on general methodology. For example, the first graph depicts the terminal descent rate as a function of coating thickness (mils) and chaff diameter (mils). The curves predict a slower terminal descent rate for small core diameters and thin coatings. Both of these generalizations concur with accepted theories that lighter particles with less mass will require more time to settle. The curves used to predict chaff cloud spreading and the horizontal transport of chaff dipoles illustrate larger cloud spreading and greater horizontal transport for the smaller diameter chaff dipoles, which conforms to the expected model predictions.

It is believed that both the glass fiber type and the foil type chaff completely settle to the ground. However, differences in reported chaff settling rates were identified during the data review. The SEA 1990 document concludes that the fall rate for chaff is 50 feet per minute, which produces a ground concentration of 2-3 dipoles per 2,000 square feet. The same SEA document reports that the median fall rate of the typical production chaff, at low altitudes and under still air conditions, is 4.52 inches per second (approximately 23 feet per minute), which is inconsistent with the preceding information. Another source indicated that chaff fall rates vary from 50 to 100 feet per minute (Taylor 1983). Variances in chaff settling times were also identified. For example, the 1989 SEA document reports that chaff remains aloft for 1 to 1.5 hours, which disagrees with a 10 to 12 hour estimate from the Armament Development and Test Center (Elgin AFB 1973).

The findings of the 1989 SEA document are incomplete because they do not address all potential health effects and air quality impacts. The document does not address the possible formation of inhalable particulates from chaff and issues related to compliance with the Clean Air Act. Also, the document does not include an evaluation of the air toxics produced from the chaff impulse charges and the potential health impacts from chromium compounds present in some impulse charges.

4.4.2.2 Analysis of Chaff Materials

In addition to reviewing past studies on chaff, several databases were accessed through the DIALOG Information Retrieval Service. The literature search conducted was centered on chaff as the major topic. To narrow the scope, chaff was paired with other key words such as air pollution, combustion, countermeasure, components, materials, and emission. The key words were used to search nine DIALOG databases (Aerospace, Chemical Exposure, Current Technology, Metadex, Inspec2, Pollution Abstracts, NTIS, and PTS). The DIALOG literature search did not uncover any new data, research, or other documentation addressing emissions or air pollution associated with chaff usage, emission factors for hazardous air pollutants generated from pyrotechnic chaff use, or the effect of chaff release on air quality.

Accumulated information on chaff composition is presented in Section 4.2. Typically, chaff consists of either type E glass fibers coated with a high purity aluminum and stearic acid, or V-bend aluminum foil dipoles which are slip and strip coated. A typical aluminum coated glass dipole is approximately 1 mil (0.001 inches or 25.4 μm) in diameter and 0.38 to 2 inches in length. Superfine dipoles with a diameter of 0.0007 inches (17.78 μm) are also used. Foil chaff is cut into dimensions of 0.00035 inches thick and 0.004 inches wide. The foil type chaff cut lengths are similar to the glass type chaff to produce similar radar interference.

Some chaff dispenser debris may survive and fall to the ground; however, no burning materials reach the ground. Chaff dispenser debris consists of a small plastic piston and an end cap (both are one inch square and one-eighth inch thick) for RR-170 A/AL type chaff. Debris from RR-144A/AL chaff consists of the remains of a plastic container, a steel firing pin, a spring, aluminum shield tape, and plastic. Expected debris for the RR-112A/AL chaff includes foil laminated kraft board containers and two polystyrene support pieces. The chaff dispenser debris remains intact and is essentially non-biodegradable. On the ground, this debris will have no impact on air quality.

Recent Air Force guidance states that chaff may be employed on all approved ranges and MOAs between 300 feet AGL and 25,000 feet MSL. Chaff cannot be dropped over Wilderness Areas, Wilderness Study Areas, National Parks, and populated areas. Based on this information, it appears that air quality impacts on PSD Class I areas are a major concern.

The detonation charge used for pyrotechnic chaff is provided by an impulse cartridge. None of the cartridges currently used for chaff contains hazardous air pollutants. Previously, the BBU-35/B impulse cartridge used with RR-170 type chaff contained calcium chromate ($CaCrO_4$), which could result in the release of chromium compounds. It is possible that some existing chaff inventory still contains the older BBU-35/B cartridges.

Chromium is one of the 189 compounds listed by the Clean Air Act as a hazardous air pollutant, and is recognized as a carcinogen; however, an emission standard has not yet been developed. At this time, the American Conference of Governmental Industrial Hygienists (ACGIH) recommends a threshold limit value for chromium (VI) of 0.5 mg/m^3. In addition to the health hazards associated with chromium compounds, special consideration should be given to chromium emissions because of their pending regulated control.

The aluminum foil type chaff is made of aluminum foil coated with a slip coat (stearic acid). During the 1950s, lead was added as a pin stripe on the aluminum foil prior to the foil being separated into strips (SEA 1989). Another source indicated that the lead content was reduced by 75 percent years ago (Wright-Patterson AFB 1956). No air quality information or data concerning possible lead particulates released from aluminum foil type chaff were found. According to current manufacturing specifications, lead is no longer used in the production of aluminum foil type chaff.

Further information on the toxicity of chromium and lead is provided in Appendix E.

4.4.3 Data Gaps and Unresolved Issues

No existing information specifically concerning air quality impacts from chaff usage was available. One area of concern is the chaff's potential to break down into smaller particulates upon ejection that may remain airborne. No information on the breakdown of chaff dipoles to dust particles could be obtained. The percentage of chaff dipole mass that might form a dust and the potential dust particulate size distribution needs to be identified to evaluate conformance with the PM_{10} standards for respirable particulates.

Assuming that a fraction of the chaff breaks down and produces some dust particles, additional information on chaff release areas (in square miles) and altitudes is needed. If specific altitude profiles are not available, an average deployment level may be substituted to estimate the chaff dust concentration. An estimate of the typical chaff release altitudes by location can be used if a complete breakdown of actual altitudes is not available. To calculate the maximum one-hour concentration, the maximum number of chaff bundles released over a given area within a one-hour period, the land area (in square miles), and release altitudes are needed.

If chaff containing lead is still used, quantities of lead involved and parameters for use (as described above) also need to be ascertained to calculate concentrations of lead. Similarly, continued use of chaff with older BBU-35/B impulse cartridges would require further information to calculate chromium emissions. This is addressed in more detail in Section 5.5.

4.4.4 Conclusions and Recommendations

Based on the limited available data for chaff, it is difficult to provide any definitive conclusions regarding air quality and health impacts from chaff use. It appears that chaff use does not lead to particulate emissions, assuming that no significant breakdown occurs in the chaff material. The minimum diameter of the finest chaff is greater than 10 microns, the threshold for regulated particulates. There is concern that air toxics may be produced during the use of some older chaff units.

Two additional studies are recommended. First, additional testing/data gathering is recommended to quantify and qualify the products formed by combustion of the chaff impulse charge. Specifically, all the combustion products containing chromium must be identified and their weight percentages determined since chromium compounds are hazardous air pollutants. If chaff with initiators containing calcium chromate are no longer available, however, this effort may not be necessary.

Second, additional testing/data gathering to determine chaff breakage is recommended. Chaff dust formation and the size distribution must be determined to evaluate compliance with the Clean Air Act for respirable particulates. It is believed that most chaff fibers maintain their integrity after ejection, in order to be effective in reflecting various radar signals (the length of the fiber determines the frequency of signal reflected). Fibers that maintain their original size are not regulated as respirable particulates. Some fibers likely fracture during the ejection. Whether they break up into particulates with an equivalent diameter of 10 microns or less is not known. If those data can be obtained from manufacturers or through laboratory testing, an estimate can be made of the potential concentration of PM_{10} for a one-hour and annual maximum. The one-hour maximum concentration could be based on a reasonable worst-case exercise scenario. Annual concentrations could only be conducted on a site-specific basis, but an initial estimate could be made for the area with the highest concentration of use (Utah Test and Training Range, according to Table 2.4-1). If impacts are insignificant there, it can be surmised that they would also be insignificant at lower-use areas, depending on their attainment status for PM_{10}.

4.5 PHYSICAL RESOURCES

4.5.1 Issues Pertaining to Chaff Use

This section addresses the effects of chaff on earth resources, primarily soils, and water resources. The primary issues relating to the use of chaff include:

- Effects of chaff on soil chemistry.
- Potential for accumulation of chaff in water, at or below the surface.
- Change in rate of sedimentation and subsequent loss or degradation of wetlands.
- Change in water chemistry.
- Effects of chaff in public drinking water systems.

Factors affected the potential for chaff to change soil or water chemistry include the chemical composition of chaff, background soil and water chemistry and conditions, and the potential concentration of chaff on the land surface or in a water body. Alteration of the natural soil chemistry also has the potential to affect vegetation and the quality of surface and ground water through leaching and surface runoff.

4.5.2 Summary of Existing Literature/Information

4.5.2.1 Soil Chemistry

There are no studies available that provide any substantive data regarding the effects of chaff on soil chemistry. Professional judgement and speculation relating chaff composition to general soil conditions and potential impacts to soil chemistry have been offered in a number of studies that address the use of chaff.

The chemical make-up of chaff is discussed in detail in Section 4.2 of this document. In general, the major components of chaff include silica, aluminum, and stearic acid. Silica (silicon dioxide) is composed of oxygen and silicon, forming the framework of the most common mineral group, the silicate minerals. Silica is inert in the environment and does not present an environmental concern with respect to soil chemistry. Aluminum is the third most abundant element in the Earth's crust, forming some of the more common minerals like feldspars, micas, and clays. Concentrations ranging between 10,000 and 300,000 parts per million (ppm) have been documented as common values for aluminum occurrence in natural soils (Lindsay 1979). These values vary depending on numerous environmental factors including climate, alkalinity/acidity of the soil moisture (e.g., solubility is much lower at neutral pH), parent rock material from which soils were formed, vegetation, etc. Aluminum eventually oxidizes to Al_2O_3 over time, depending on the original size and form of the aluminum or aluminum compound and the environmental conditions mentioned above. Stearic acid is an animal fat which will degrade when exposed to light and air.

No studies are available that document field investigations to determine whether site conditions at training areas are affected by the accumulation of chaff. Similarly, no studies have been documented that determined, through soil sampling or otherwise, the effect of chaff use on soil composition. Based on levels of use, there is little likelihood that chaff concentrations could reach a level that would affect the composition of the underlying soils. In a worst case scenario (i.e., release of a chaff bundle 500 feet above the ground with negligible wind speed between release point and the ground), the concentration of chaff at the ground level has been estimated at 6.8 mg/m^2, which equates to 2.7 mg/m^2 of aluminum. However, this does not address the accumulation of chaff over many years of use.

4.5.2.2 Water Resources

Literature that includes any significant discussion of the affects of chaff on water quality and aquatic habitats is scarce. Studies conducted by SEA for Strategic Air Command and the National Guard Bureau included literature searches and addressed the environmental impacts of dispensing chaff from aircraft (SEA 1989 and 1990). Each of these studies contains much of the same information relating to the affects of chaff on water resources and water quality and cites the following conclusions:

- Chaff and chaff-coating materials are insoluble in water; in a water environment, chaff would either drop to the bottom of a water body or would be driven across the water surface into leeward areas by any prevailing winds, where it would be deposited along shorelines or in shoreline vegetation.

- Chaff introduced into public drinking water sources would be readily filtered out by standard screens and settling tanks presently in place.

- Under laboratory conditions, a 13-day experiment showed no appreciable increases of aluminum, cadmium, copper, iron, or zinc levels in chaff-spiked salt water from the Chesapeake Bay. The only detectable increases were in the low parts per trillion range.

Other documents that assessed impacts of dispensing chaff include an EA for the Utah Test and Training Range and a number of EAs conducted at Eglin AFB in Florida. Findings within the Utah EA included the determination that there would be no anticipated effect on sedimentation, water temperature, or dissolved oxygen content from the introduction of aluminum and/or aluminum coated glass fiber chaff into a water body. Furthermore, the small amounts of aluminum hydroxide introduced to a water body from chaff would be insufficient to cause any change in water pH. These determinations were based on assumptions of the author and lacked the support of scientific data.

The Eglin AFB EAs concluded that impacts to water environments are unknown, but after more than 25 years of chaff use on the range, there were no known or reported adverse effects on water, land, or wildlife. Based on the worst-case scenario described above, a maximum of 184 chaff fibers per square meter could be expected from a release at 500 feet AGL. This would represent the maximum amount of deposition on the ground that could be expected from the release of a single bundle of chaff. There are no similar estimates for accumulation on water bodies. Many documents reference activities at other ranges to support their own findings of no impact. For example, the Utah EA cited that on the Nellis Range, utilized the last 8 years for chaff drops with an average of 50 drops per week, there is no visual indication of chaff accumulation on the ground (Taylor 1983).

4.5.3 Data Gaps and Unresolved Issues

It is evident that meteorological conditions, size of the dispersal area, number of training operations discharging chaff, and environmental factors are site-specific considerations that need to be evaluated in assessing the deposition and concentration of chaff on the ground surface. Environmental factors would include topography, climate, and vegetation, among others. For example, chaff deposition in a desert environment with high winds and few topographic features may be more prone to physical weathering from abrasion by sand particles; topographic features could provide areas where chaff could accumulate, protected from wind; or a well-vegetated environment may provide for more acidic soil conditions, contributing to the chemical weathering of the aluminum in the chaff.

Existing documentation on chaff indicates that data on the effects on water resources are lacking, and that no studies have been conducted to assess the effects of chaff accumulation on wetlands or aquatic ecosystems. However, conclusions are drawn that impacts on water resources are not anticipated based on the overall wide dispersion and minimal toxicity of the constituents of chaff. Very few, if any, documents provide scientifically sound data to back up conclusions made on the effects of chaff accumulation in water environments. Overall, water chemistry data is lacking for all water quality conditions and temperature variations, with the exception of the Chesapeake Bay salt water study. Even this experiment could be repeated to verify the findings and to provide a statistically sound data set. No studies have been conducted to determine the fate of chaff fibers once introduced to a water environment; for example, whether fibers collect in leeward areas of a water body and, if so, whether wind and waves facilitate fragmentation and subsequent deterioration. Unresolved issues include the effects of chaff and associated physical build-up on aquatic plant growth and on the physical aspects of streams and wetlands, including the rates of sedimentation or erosion.

4.5.4 Conclusions and Recommendations

The potential for significant effects from chaff deposition on soil is considered to be low. Nevertheless, a limited analysis is recommended to provide a scientific basis for impact conclusions. This effort would involve field reconnaissance at ranges that have historically used chaff to see if chaff accumulates in certain areas. For example, field surveys could include examination of areas where wind-blown sand is deposited to see if chaff is also accumulating in those areas. Soil samples would be collected at a control, or background, location and in chaff accumulation areas discovered during site reconnaissance. The samples would be analyzed in a laboratory to determine whether there are any discernable chemical differences that can be attributed to the chaff.

The overwhelming conclusion in documents that address the dispensing of chaff from aircraft is that chaff would have no effects on water resources. Although most of the substances in chaff are nontoxic and inert and seemingly support these conclusions, some (like Boron) are EPA-listed under the Safe Drinking Water Regulations (EPA 1992). Laboratory or field experiments could be conducted to verify and support the conclusions of no impact to water quality. Field studies could include a program of water quality sampling in wetland areas or water bodies that are exposed to chaff build-up. Laboratory experiments could examine the effects of chronic exposure of chaff to different water quality parameters, such as temperature, alkalinity, and pH. Most documents tend to disregard the issue of physical accumulation or build-up associated with the deployment of chaff. However, no studies have been conducted to support this conclusion. Studies could be designed to determine the effects of long-term collection of chaff and chaff by-products on water resources and aquatic ecosystems. For example, field or laboratory test plots of aquatic vegetation could be studied to access the effects of chaff build-up growth.

4.6 BIOLOGICAL RESOURCES

4.6.1 Issues Pertaining to Chaff Use

The primary potential impacts and concerns pertaining to the effects of chaff on biological resources include:

- Startle effects on birds and other wildlife upon chaff release.
- Adverse effects on wildlife from ingestion or inhalation of chaff.
- Physical effects on the skin and/or feet of wildlife (e.g., birds using chaff as a nesting material, chaff becoming embedded in the paws of animals, etc.).
- Interference with wildlife activities, such as echolocation by bats.
- Effects on vegetation from chemical changes in the soil.
- Chemical changes to ground and/or surface water and the resultant adverse effects on aquatic life.

Analysis of biological resource issues pertaining to chaff use includes the potential impacts caused by the physical characteristics of chaff (single dipoles or bunches) and the potential toxic effects of the materials that compose chaff (silica, aluminum, and stearic acid).

4.6.2 Summary of Existing Literature/Information

4.6.2.1 Startle Effects on Birds and Wildlife on Chaff Release

Startle effects on birds and other wildlife species resulting from the release of chaff (and possible glare caused by light reflecting from the falling chaff cloud) are expected to be negligible. Recent reviews (Gladwin et al. 1987; Manci et al. 1988) have established that military overflights often elicit startle responses from a wide variety of animals; the startle effect from the noise and presence of the aircraft itself would overshadow any additional effect from the chaff release.

4.6.2.2 Adverse Effects on Wildlife From Ingestion or Inhalation of Chaff

Though it is unlikely that animals would selectively feed on chaff, it is reasonable to assume that some chaff consumption would occur during normal feeding routines by animals inhabiting areas beneath or downwind of areas in which chaff is released. As discussed in Sections 4.2, the primary chemical components of chaff are generally considered nontoxic. Studies (Browning 1969; Venugopal and Luckey 1978) have shown that the toxicity of orally ingested aluminum is very low in animals, and pure silicon dioxide is inert. Thus, oral exposure to the small concentrations of chaff present on the ground beneath training areas would not be expected to cause adverse toxicity-based impacts to wildlife. Stearic acid is a natural compound that can be metabolized (digested) by animals. The small amount present on chaff dipoles would have negligible food value.

The Canada Department of Agriculture conducted a study (Barrett and MacKay 1972) in which domestic calves were fed amounts of chaff to "simulate the risk of very heavy exposure in the field to this material." Calves were either fed 0.25 ounces (approximately 7 grams) of chaff for 14 days or 0.125 ounces (3.5 grams) of chaff for up to 39 days. The calves, when hungry, rejected intact clumps of chaff and largely rejected chaff when scattered amongst their daily ration of dry meal. The calves readily consumed the chaff only when molasses was poured over it and it was then thoroughly mixed into dry meal. No evidence of digestive disturbance or other clinical symptoms were observed among the calves during the trials, and both groups gained weight at the same rate as the control calves. Blood samples taken at the start and end of the trials showed no deviation from normal. Postmortem examinations of parts of the digestive system and major organs showed no lesions of pathological significance that could be attributed to the chaff. "A few small fragments" of chaff were found trapped between the villi of the reticulum, but they did not appear to provoke any cellular reaction to their presence. A letter in the Occupational and Environmental Health Laboratory files from the chairman of the Department of Dairy Husbandry at the University of Wisconsin described a similar study using cattle and goats. The study noted that the animals avoided consuming intact chaff and concluded that chaff presented no health hazards to farm animals (Taylor 1983). No claims have been filed with the Claims and Tort Litigation Branch of the Judge Advocate General's Office that alleged the loss of livestock from ingestion of chaff for well over ten years (SEA 1989).

The U.S. Navy contracted a study (Block and Schiff 1977) on the effects of chaff on six marine organisms in Chesapeake Bay: a benthic polychaete worm (*Nereis succine*), various life stages of the American oyster (*Crassostrea virginica*), the blue mussel (*Mytilus edulis*), the blue crab (*Callinectes sapidus*), the filter-feeding menhaden (*Brevoortia tyrannus*), and the killfish (*Fundulus heteroclitus*). The organisms were exposed to concentrations of chaff that were much higher than the concentrations that would result from normal chaff training operations. No significant increases in mortality were noted, and the study concluded that the continued use of chaff at rates similar to those already in use by the Navy would have no environmental impacts on the Chesapeake Bay ecosystem.

A study by United Kingdom Health and Safety Executive for the Ministry of Defense (UKHSEMD) (1988) at RAF Spadeadam reported that the potential for the ingestion of chaff was highly likely in grazing animals and could potentially lead to gastrointestinal blockages (although no cases have been reported). In relation, it has been suggested that the digestive systems of wild animals are more efficient than livestock, leading to the conclusion that such animals would have an even greater capability to pass the chaff through their digestive systems (SAIC 1992).

The potential for chaff accumulation on the surface of standing water bodies would be slightly greater than the potential for accumulation on land. Chaff on dry land would tend to be blown about by wind, trapped by rocks and vegetation, and generally subject to disintegration due to abrasion from surface features. In contrast, chaff fibers that land on standing water could float and potentially accumulate on the leeward side of the water body, with little fragmentation due to abrasion. Because material tends to accumulate on the leeward side of standing water bodies, surface-feeding animals also generally feed in these areas. Although it appears likely that wildlife would avoid ingesting chaff, if a large quantity of chaff was present on a water body and consumed by a surface-feeding duck, physical compaction of the chaff in the gizzard could occur. While some birds have developed gizzards that use ingested sand as a digestion aid, the gizzards of surface-feeding ducks are not effective in dealing with such foreign materials. In addition, while some bird species routinely regurgitate hair, feathers, and other foreign material commonly ingested during feeding, surface feeders do not have this ability. If a surface-feeder ingested chaff, it is possible that the fibers would pass through the duck's digestive system as does fibrous plant material, and not be harmful to the duck. Although no direct data on this subject are available, it cannot be ruled out that physical compaction could occur, in an extreme case, and death could result.

As with any small particles in the environment, some inhalation of chaff by wildlife and livestock would be expected. Inhalation could occur during chaff releases as the dipoles drifted to the ground. The potential for inhalation and ingestion by livestock and humans was examined in the UKHSEMD study, which showed that any particles inhaled would be too large to penetrate the larynx and would be expelled through the nose or swallowed. Once on the ground, the dipoles tend to break up readily when agitated by wind or water currents or when crushed by the movement of humans, animals, or machine. Any activity which would stir up dust (animal movement, wind, etc.) could potentially resuspend the chaff particles, rendering them available for inhalation by animals. The chaff dipoles are larger than asbestos fibers and would not be likely to cause cancer. Chronic inhalation of chaff could cause an inflammatory response in the respiratory system, potentially resulting in silicosis. The diameter and length of the dipoles is important in determining how far into the respiratory system they could penetrate and how easily they could be cleared out. However, relative to the background concentrations of dust in the air, the amount of additional particles contributed by military chaff-release operations would be negligible.

4.6.2.3 Physical Effects on the Skin and/or Feet of Birds and Wildlife

Chaff is similar in form to fine human hair; due to its flexible nature and softness, external contact with chaff would not result in adverse impacts to wildlife. The hair or feathers covering wildlife bodies and their hooves or tough foot pads would minimize the potential for direct skin contact with chaff dipoles, and it is very unlikely that chaff could become embedded in the skin and/or feet of any animal. It is possible that small mammals or birds could use chaff for nest material if it falls to the ground in discrete clumps. Because none of the materials composing chaff are considered toxic or harmful (with the possible exception of lead in older foil-type inventory), no adverse reactions would be expected even after prolonged contact.

4.6.2.4 Interference with Wildlife Activities

Fairly dense clouds of falling chaff could temporarily affect flying bats by creating clutter that could confuse them when using echolocation to avoid obstacles and to hunt for insects. The impacts would be short term because chaff quickly dissipates in the air and because the bats would recover quickly from the confusion. Bats would not likely misinterpret the chaff particles as insects and so would not likely consume them.

Large quantities of chaff in aquatic or terrestrial habitats could cause some animals to avoid these areas, thereby reducing available habitat.

4.6.2.5 Effects on Vegetation From Chemical Changes in Soil

Both aluminum and silica are major constituents in the earth's crust and occur commonly in soils. Silica is inert and would have no effect on soil quality. Aluminum is also relatively inert and is highly resistant to corrosion. Metallic aluminum oxidizes and combines chemically to form oxides, sulfides, and metallic salts. Aluminum and most of its common compounds are insoluble except in acidic conditions. Since the average concentration of aluminum naturally occurring in soils is 71,000 mg/kg (approximately 1,065,000 mg/m^2) any addition of aluminum to the soil from chaff would be negligible. Considering the very small amount of aluminum deposited and the relative inertness of chaff, no adverse effects on soil quality are expected (see Section 4.5). Stearic acid, which is used to coat the aluminum and silica fiberglass, is a natural compound that is biodegradable and is used as a carbon source for microorganisms in many laboratory experiments (Taylor 1983). Its presence in chaff fibers would have no adverse effects on the environment.

A significant increase in uptake of aluminum by plants would not be expected. Under normal circumstances, plant tissues contain levels of aluminum that range from approximately 29 to

1,400 ppm, depending on the species and location. Any uptake of aluminum which could be attributed to the presence of chaff in the soil would be negligible and would not result in toxic effects. Adverse physical effects on plant life from chaff deposition are also unlikely, given the lack of toxicity of the materials in the chaff fibers and the small amount that could possibly remain deposited on vegetation.

4.6.2.6 Chemical Changes to Ground and/or Surface Water and the Resultant Adverse Effects on Aquatic Life

The material in chaff is relatively insoluble in water, and chemical changes to water bodies from chaff deposits are not expected. Natural concentrations of aluminum in fresh water bodies have been reported as high as 10 mg/liter. Even under the assumption that the majority of chaff would land directly on a water body over a year's time, any leaching of aluminum would be slight, and a notable increase in aluminum concentrations would be unlikely. A study in 1976 showed that after 13 days there was no appreciable increase in the levels of aluminum, cadmium, copper, iron, or zinc in Chesapeake Bay water spiked with chaff (Block and Schiff 1977). Resultant effects on aquatic life are not expected. No studies have been conducted to assess the effects of chaff in anaerobic conditions such as in swamps.

4.6.3 Data Gaps and Unresolved Issues

Few conclusive studies on the effects of chaff on wildlife have been conducted. Two studies on the effects of chaff ingestion on cows (MacKay 1972 and USAF 1983) concluded that chaff presented no health hazards to farm animals, and a study on the effects of chaff on the Chesapeake Bay ecosystem (Block and Schiff 1977) concluded that there were no environmental impacts from chaff on that system. These studies do not provide enough evidence to conclude that chaff is harmless to all animals. Studies testing a variety of potential effects on a variety of species and habitats would be needed to make this conclusion. There are no data on the decomposition process of chaff in anaerobic conditions such as swamps, or on the solubility of chaff in animal stomach acid. Some additional data gaps that could be studied include effects on newborn birds and rodents when chaff is present in nesting material, effects of chaff ingestion on surface-feeding ducks, and effects of ingestion on small herbivores such as rabbits.

4.6.4 Conclusions and Recommendations

The summary of findings from existing literature and information leads to some observations on the likelihood of various types of impacts of chaff on biological resources. It does not provide a comprehensive analysis applicable to specific species. However, on a site-specific basis, individual locations will be concerned about specific species, particularly if threatened and endangered species are present. Based on general knowledge about the physiological behavior of various types of animals, a preliminary assessment can be made of the probability of exposure and resulting impact on major animal groups. These are presented in Table 4.6-1. Specific consequences may vary as a result of a wide variety of factors, including location, habitat and habitat condition, species, and time of year.

Table 4.6-1. Probability of Exposure and Impact on Animals

Animal Groups	Exposure Pathways				Impacts	
	Direct (Chronic) Skin Contact	Inhalation (lungs/gills)	Ingestion	Noncontact Visual (sonar)	Direct (short-term)	Indirect* (short- to long-term)
Invertebrates (aquatic/terrestrial)	3	2	3	NA	Negligible	Negligible
Fish and Shellfish	NA	2	1	NA	NA	NA
Freshwater Amphibians and Reptiles	1	1	1	NA	NA	NA
Terrestrial Birds	2	2	2	1	Marginal	Marginal
Aquatic Birds	2	2	2	2	Negligible	Marginal
Small Mammals	2	2	2	1	Marginal	Marginal
Large Herbivores	2	2	2	1	Marginal	Marginal
Carnivores	1	2	2	1	Marginal	Marginal
Bats	1	2	2	3	Marginal	Marginal

*Indirect impacts include bioaccumulation

Probability of Exposure
1: Improbable ($<10^{-6}$/hear)
2: Remote (10^{-4}/year)
3: Unlikely (10^{-2}/year)
4: Probable (10^{-1}/year)
NA: Not Applicable

Based on available information, it does not seem that aircraft-released chaff produces any adverse effects on plants or animals. Because the materials contained in chaff (aluminum, silica, and stearic acid) are basically inert or nontoxic, potential health hazards to wildlife or livestock are not expected due to ingestion. The wide dispersion pattern associated with the release of chaff are expected to produce such small concentrations of chaff on exposed land that no biological impact is anticipated to plant life or wildlife due to physical deposition, chemical changes to soil or water, or inhalation by animals. Nevertheless, field and laboratory studies are recommended to verify these conclusions.

Some potential effects of chaff on biological resources have not yet been analyzed. Recommendations for studies to help answer these data gaps include: (1) field surveys to quantify the amount of chaff present in arid and moist terrestrial environments and sampling of aquatic (freshwater) habitats for surface and bottom accumulation of chaff; (2) if accumulation is found, studies to evaluate potential impacts on birds and small mammals; (3) laboratory study on chaff decomposition under anaerobic conditions versus aerobic conditions over several months; and (4) laboratory study on the solubility of chaff in stomach acid.

To conduct these studies, a step by step method should be applied with each consecutive step based on the last. For example, to study the effects of chaff on newborn rodents and birds, one would first conduct transect surveys downwind of chaff release areas where chaff would likely accumulate to see if chaff is visibly present. If chaff is present and fairly common, then bird nests, woodrat nests, and burrows in the vicinity would be checked for chaff in nesting material. If chaff is found, newborn birds and rodents would be examined for adverse effects such as skin irritation due to the chaff. A similar multi-step study would be necessary to assess the potential for impacts on waterfowl.

If, during field study, relatively fresh animal carcasses are discovered, the stomach contents could be examined for presence of chaff. However, such incidental findings would not constitute a statistically representative sample, and no conclusions could be drawn about whether ingestion of the chaff caused any physiological effects on the regional populations. It would merely confirm that chaff had been ingested.

4.7 LAND USE AND VISUAL RESOURCES

4.7.1 Issues Pertaining to Chaff Use

Land use effects result when a particular land use is altered or displaced. Land can be owned or controlled by federal entities (such as the Department of Agriculture, National Park Service, Bureau of Land Management, Department of Defense), states or local jurisdictions, or by individuals. Each of these entities determines suitable land use based on some objective or benefit. The benefit can be economic, ecological, social (public), or personal.

Visual resources are impacted by changes in the environment that affect personal visual perceptions of a place. Particular visual attributes of the environment may be valued for the feelings they tend to evoke in the majority of people. Places that are highly valued are considered important visual resources. When visual attributes are altered sufficiently to elicit altered feelings about a space, a visual impact results.

The two primary issues concerning impacts from chaff use in military training are:

- Effects on the use of an area for existing, designated, or planned land use.
- Whether chaff training operation leave visual evidence that affects the visual quality of an area.

The primary factors to be considered in evaluating land use effects are land ownership, land management objectives of the owner/custodian, current land use, and the quantity of chaff by-products that may enter the environment and accumulate. The primary factors to be considered in evaluating visual effects are the visual quality of the area and the visibility of accumulated chaff.

4.7.2 Summary of Existing Literature/Information

No studies have been identified on the effects of chaff on land use or visual resources. A search was conducted of the DIALOG database, including the NTIS and Sociological abstracts, using combinations of key words, including chaff, litter, visual resources, visual resource management, agriculture, recreational use, landscape, aesthetics, parks, forest, and land management. No citations relating to or analogous to this topic were retrieved. A search of the LIBROS database at the University of New Mexico using similar key words yielded some articles, mostly from the 1970s. The Bureau of Land Management library in Denver indicated that BLM documents are listed in the On-Line Computer Library Center (ONLC). This database is included within the LIBROS database. The U.S. Department of Agriculture Forest Service Information Center Service is only available for internal (Forest Service) use. Direct contact with agencies was limited to the Forest Service, Intermountain Research Station offices in Ogden, Utah and Missoula, Montana. Some information on litter in forest areas was available from these sources.

4.7.2.1 Land Use

The methodology for assessing effects on land use from chaff activities involves six steps. The first step is to identify whether the training area is over land or open water. The second step is to determine if any populated areas underlie the chaff training area. The third step identifies ownership of underlying land. The fourth step has two parts: determining whether there are any specially designated areas with specific land management objectives and, if not, identifying other land uses. The fifth step incorporates information on effects of chaff on particular resources, such as soil, water, vegetation, or animals, to determine how they, in turn, affect particular land uses. The sixth step would identify acceptable levels of chaff use (as an average debris density over a square mile in a year, for example) for each type of land use. Table 4.7-1 identifies the sensitivity of various land uses to various types of potential effects from chaff use.

If training is over open water, no effects on the use of ocean resources are anticipated (such as effects on commercial fishing) due to dispersion of chaff material and lack of determinable effects on marine life (see Section 4.6). If open water areas are close to shorelines (at some distance to account for wind, water movement, and distance covered by aircraft during high speed training), effects should be considered in a similar manner as over-land training.

Most military training, including chaff training, is generally done over rural and remote areas. Densely populated areas are generally avoided and would be unlikely to experience any impacts. However, chaff use in high altitude MOAs may not avoid small towns or isolated residences.

Table 4.7-1. Sensitivity of Land Uses and Specially-Designated Areas to Resource Impacts from Chaff Training

Land Use or Specially-Designated Area	Potential Resource Effect						
	Wildlife	Livestock	Plants	Soil/Water	Aesthetics	Chaff Accumulation	Debris Accumulation
Wilderness/Wilderness Study Area	H	M	H	H	H	H	H
Wild and Scenic River	H		H	H	H	H	H
Coastal Zone	H		H	H	H	H	H
Wildlife Protection Area/Refuge	H	N/A	H	H	M	H	H
Park/Monument	H	N/A	H	H	H	H	H
Military	L	L	L	L	L	L	L
Forest - Natural	M	L	H	H	M	M	M
Forest - Commercial	M	L	H	H	L	L	L
Cropland	M	M	H	H	L	M	M

H = High
M = Medium
L = Low
N/A = Not Applicable

Table 4.7-1. Sensitivity of Land Uses and Specially-Designated Areas to Resource Impacts from Chaff Training (continued)

Land Use or Specially-Designated Area	Potential Resource Effect						
	Wildlife	Livestock	Plants	Soil/Water	Aesthetics	Chaff Accumulation	Debris Accumulation
Rangeland (livestock grazing)	M	H	H	H	L	L	L
Recreation	H	L	M	M	H	H	H
Industrial	L	N/A	L	L	L	L	L
Residential	M	N/A	M	M	M	H	H
Commercial	L	N/A	L	L	L	L	L

Land ownership of areas underlying chaff training airspace is a factor in determining potential impacts from chaff use. The primary distinction is whether the underlying land is owned or controlled by DOD or some other entity. If the land is controlled by DOD, its primary use is usually military test and training operations. Such areas would be compatible with chaff training operations, although some cleanup standards may be desirable. If joint uses are permitted on DOD lands for activities such as grazing or recreation, these uses should either continue with appropriate advisories to users (with no further analysis required), or if joint use objectives are sufficiently strong (based on natural resource management planning), these areas should be further analyzed.

Other federal agencies that have ownership and control of large portions of real estate are the Department of Agriculture (particularly the Forest Service), and the Department of the Interior (particularly the BLM and National Park Service [NPS]). Land may also be owned by state or local government and private entities. Depending on ownership, different land management objectives can be anticipated. Some agencies have detailed land management plans and objectives for specifically designated areas. In general, Forest Service and BLM resources are managed for multiple use, but specific characteristics may promote different objectives (such as more restricted access in sensitive areas).

Where formal land use objectives are not specified or where mixed uses occur, impacts will vary among land uses. Different land uses have different sensitivity to external influences such as the effects of chaff training. Broadly speaking, the effects are related to accumulation of chaff fibers, and casings and components debris.

<u>Specially Designated Areas</u>

Wilderness Areas, Wilderness Study Areas, and Wild and Scenic Rivers share objectives to maintain solitude, naturalness, specific features, and primitive and unconfined recreational opportunities. These areas are managed in the strictest way to maintain these qualities, and any discretionary source of manmade intrusions are restricted in terms of the land management objective. Coastal zone management areas may have specific land use and development objectives and limitations.

Areas designated for protection of wildlife or ecological systems are usually sensitive to changes in existing conditions. Specially designated areas include wildlife refuges/sanctuaries, bird sanctuaries, Areas of Critical Environmental Concern, and coastal zones. These areas are intended to provide advantageous conditions for plants and wildlife. If chaff fiber accumulation were to adversely affect these conditions, it could secondarily affect the suitability of the land for preservation purposes. Effects of ingestion, inhalation, and use of chaff fibers for nesting still need to be studied (see Section 4.6). On the other hand, introduction of chaff into an environment may be less detrimental than the presence of people for the well-being of some animals. (Many military ranges have proven to be havens for wildlife despite the many manmade intrusions on the environment). Long-term effects of chaff accumulations on wildlife management areas will depend on the results of studies of effects on wildlife.

Other sensitive areas include National Parks and Monuments, which have recreational uses and generally high visibility and visitation. Analysis of these areas is discussed under recreational land use below.

Agricultural Lands

Commercial forests and croplands are not likely to be affected by chaff fiber accumulation, and chaff casing debris should have little effect on productivity. Chaff ingestion was concluded to have no acute adverse effect on livestock (see Section 4.6). Long-term effects on livestock are unknown and perhaps not a concern, since commercially bred livestock do not have long life expectancies.

Public perception of potential food contamination can affect marketability of products. Chaff fibers could be perceived as a contaminant and affect consumer buying and, thus, the viability of agricultural land use in chaff use areas. The data on toxicity of chaff materials indicates this should not be a concern, however (see Section 4.2.2).

Mining and Industrial Land Uses

Mining and industrial activities should not be affected by chaff debris, although if these activities involve population centers, military operations may need to avoid these areas. Chaff casing debris may get tangled in some agricultural, industrial, or mining machinery.

Recreation

Recreational activity is one of the primary uses of rural and remote areas. This includes hunting, fishing, swimming, boating, camping, picnicking, hiking, sight seeing, and wildlife watching. A key benefit from recreational activity is enjoyment. Activities that affect enjoyment, and consequently choices about how and what areas are used for recreation, would be incompatible uses if they result in altered use of an area or a reduction in its suitability for recreation. Depending on conclusions reached about the effects of chaff fibers and debris on wildlife, it is probable that chaff training operations would have little effect on hunting and fishing resources. The biggest issue affecting compatibility with recreational uses is public attitudes about litter.

Chaff debris is similar to other litter introduced by man and becomes a visible component of the environment. Public attitudes about litter can affect use of an area, particularly primitive recreation areas where people are trying to "escape civilization" and enjoy the natural environment. Some litter is usually found in urban and suburban environments and, although not desirable, it is not as noticeable in areas where manmade structures predominate. In more remote natural areas where chaff training is typically performed, litter is likely to be more annoying to people and therefore more likely to affect how people feel about an area and their willingness to pay for recreation. However, chaff litter is expected to be an extremely small component of the litter typically encountered in recreation areas.

The U.S. Forest Service has used various techniques to tackle litter problems in both heavily and sparsely used recreational areas. Incentive programs (where rewards are given to participants who help with clean up) and education programs (such as the "pack it out" approach) have had fairly good success in aiding rangers in clean up. Areas near roadways, picnic sites, and camping areas receive more litter, but they are also easier to clean up due to accessibility. Backcountry and remote areas have more diffused litter, higher sensitivity, lower litter "carrying capacity," and are more difficult to maintain. Most litter is seen in camping areas and along trails. The amount of chaff litter that would actually fall in an area where it would be noticeable is very small.

For certain areas, litter will be a larger issue than others. This can be determined from local Forest Service, NPS, and BLM managers.

Residential Areas

Scattered homesteads, isolated ranches, and pockets of vacation residences can underlie chaff training areas. Residential use is sensitive to litter. Litter being dropped on private property from overflying aircraft may be objectionable, but the incompatibility of this practice is one of degree. The chaff itself is unlikely to affect residential use (aside from the occasional strange end cap or wrapper showing up). While the principle of intrusion and sanctity of private property may be an issue, there is unlikely to be any actual damage, and it is very unlikely to change residential land use patterns.

Commercial Use

Commercial land uses are rare in rural/remote areas where chaff training is performed. However, some small commercial businesses will be found. These could include fish hatcheries and other stock breeding, stables, convenience stores, and automobile/marina services. These areas are similar in sensitivity to residential and industrial land uses and should not be affected by chaff training. Effects on animal breeding success for commercial purposes has been found to be insignificant (see Section 4.6).

4.7.2.2 Visual Resources

Impact on visual resources depends on three factors: the quality of the visual environment, the sensitivity of the area to changes in that environment, and the degree to which chaff use (specifically, accumulation of chaff debris) affects the view. To assess the effects of the accumulation of chaff in an area, a visual quality or visual resource rating is assigned to the area. Next, the degree to which chaff debris contrasts with the setting is determined. Third, if there is a contrast, and the visual resource value is high, the sensitivity of the area would be assessed based on viewer frequency. If a potential impact is identified, it may be mitigable by restricting chaff training over the area to limit the projected density of accumulation, thus reducing the contrast to unnoticeable levels.

Visual effects of chaff debris in open water are not considered likely as it would be dispersed and unnoticeable. Chaff training areas close to shorelines may have a potential to affect coastal areas with visual sensitivity related to high recreational use and objectives for maintaining natural conditions in fragile and scarce ecological settings.

The impacts of chaff training over land will depend on the visual quality of an area. Public lands are often classified by the land custodian. Both the Forest Service and the BLM have visual resource classification systems. Table 4.7-2 lists the categories used by these two agencies and the guidelines for permissible alterations within each category. These ratings usually apply to large landscape areas and consider landform, vegetation, water features, color, adjacent scenery, unique quality, and effect of cultural modifications. BLM Class 1 (Forest Service designated "Preservation") areas have the highest visual quality, and only natural ecological changes should occur in these areas (BLM 1986a). These areas include Wilderness Areas, wild sections of national Wild and Scenic Rivers, and other Congressionally and administratively designated areas. BLM Class 2, 3, and 4 areas have progressively less levels of scenic quality, sensitivity, and distance zones, with progressively less restrictions on permissible alterations to the natural landscape. The Forest Service has comparable categories with recommend management objectives (McGuire 1974).

It has been the policy of the federal government over the last century to acquire areas of exceptional scenic quality in order to maintain control over them and allow all members of the public to benefit from them. Most of these areas would be Class 1 visual resource areas or Preservation areas. It is possible that some areas with exceptional scenic value are privately held or are not part of the usual publicly available lands.

Areas without a visual resource classification can be assigned a rating using the BLM/Forest Service method. As a general rule, mountainous areas and areas with varied terrain that have few manmade features (such as power lines, major roadways, agricultural or large mining operations) will have high visual quality potential and would warrant a rating of Class 2. All other areas would have Class 3 or 4 ratings. Interviews with local or regional agencies can help identify special features and characterize the landscape.

The BLM also has a visual resource contrast rating system for determining the effect (intrusiveness) of modifications to the existing environment (BLM 1986b). Alterations are evaluated based on form, line, color, and texture to determine whether they present high, moderate, low, or no visual contrast. Permitted levels of contrast coincide with the visual resource ranking. That is, Class 1 areas should have few contrasting elements, Class 2 can tolerate visual intrusions with low contrast, Class 3 can have moderate contrast, and Class 4 can have high contrast.

The same system can be used to categorize permissible levels of impact of chaff in the environment. Chaff debris is only perceivable in the immediate foreground; however, it creates visual contrast in the natural setting in a similar manner as larger objects in more distant landscapes. The chaff itself is unlikely to be noticeable except where there are extremely high levels of accumulation. The most noticeable components will be the incidental debris. The

Table 4.7-2. BLM/Forest Service Visual Resource Classification System

Bureau of Land Management		Forest Service	
Visual Resource Class	**Management Objectives**	**Visual Quality Category**	**Management Objectives**
1	Preserve existing character of the landscape; provides for natural ecological changes; does not preclude limited management activity; level of change to characteristic landscape should be very low and must not attract attention.	Preservation	Only ecological changes permitted.
2	Retain existing character of the landscape; level of change to characteristic landscape should be low; management activities may be seen, but should not attract the attention of the casual observer; any changes must repeat the basic elements of form, line, color, and texture found in the predominant natural features of the characteristic landscape.	Retention	Management activities not visually evident.
3	Partially retain the existing character of the landscape; level of change to the characteristic landscape should be moderate; management activities may attract attention but should not dominate the view of the casual observer; changes should repeat the basic elements found in the predominant natural features of the characteristic landscape.	Partial Retention	Management activities remain visually subordinate.
4	Provide for management activities which require major modification of the existing character of the landscape; level of change to the characteristic landscape can be high; management activities may dominate the view and be the major focus of viewer attention; every attempt should be made to minimize impacts through careful location, minimal disturbance, and repeating basic landscape elements.	Modification	Management activities may dominate but must borrow from natural landscape forms.
		Maximum Modification	Activities may dominate and may be out of scale in mid- and foreground but appear natural when seen as background.

packaging of non-pyrotechnic chaff is about the size of a small stationary box. Most are made of brown kraft paper. This packaging would only be discernible at short distances from an observer in high visibility conditions (good light, little ground cover, and brownish soil). Some chaff packages are laminated with a reflective aluminum layer. These could be visible at somewhat greater distances in good viewing conditions. Other chaff debris includes small plastic components, usually murky white in color, and small metal springs. These are only visible within a few feet of a viewer.

Assuming that only a single piece of chaff casing debris is likely to be within the foreground field of vision at a time, and given the small size of the debris compared to the entire foreground window, the contrast ranking would be low. Most casings would not contrast strongly due to color and texture. Casings have straight edges that could contrast with forms and shapes in nature, but the overall form would be irregular after being expelled from high speed aircraft and therefore less discernible from other objects on the ground. Aluminum coated casings may contrast moderately in some viewing situations.

Using the assumption that chaff debris would have low contrast, only Class 1 visual resource areas need be entirely avoided by chaff training. Class 3 and 4 areas would usually be compatible with any practicable debris densities from existing chaff training levels. These conclusions need to be verified based on field observations. Use of reflective coatings on chaff packaging may later be determined to affect Class 3 areas with high visitation. Areas with Class 2 ratings may require additional analysis.

Potential for impact in areas with Class 2 visual resource quality underlying airspace where chaff is used would depend on ground cover conditions. Dry environments may tend to accumulate chaff debris over longer time spans due to slower decomposition rates, resulting in denser litter. Ground covers with irregular qualities (varied forms, sizes, shapes, and lines); scattered, shrubby vegetation; soil surfaces with a variety of aggregate sizes (including large rocks, pebbles, and sand); dense vegetation with large or mixed leaf sizes or tufted grasses would decrease the visual contrast of small manmade objects. Ground covers with homogenous or even texture would promote higher visibility. These include open desert floors, low even grasses, and open forest with duff covering. Soil color also influences contrast, depending on the how well the object's color and texture blends into the natural tones.

Based on this information, guidelines for permissible chaff density can be derived, which would equate to a certain amount of chaff released over a given area over a year. Table 4.7-3 provides anticipated levels of impact from chaff debris on four categories of visual resource value, based on BLM visual resource categories. For this first-level study, chaff debris is assumed to be present in the environment at a density of about one component per 1,000 square feet. Only non-reflective chaff casings are considered. A limited range of representative environmental conditions were used, and results could vary depending on specific conditions. Determinations of potential impact are indicated as low, moderate, or high.

Table 4.7-3. Chaff Debris Contrast Potential

Visual Resource Rating	Representative Environments					
	Dry, med soil, open scrub	Dry, open desert floor	Dry grassland	Dry, open forest	Dry, dense forest	Wet, tall grassland w/shrubs
1	H	H	H	H	H	H
2	M	M/H	M/H	M/H	M	M
3	L	M	L	M	L	L
4	L	L	L	L	L	L

L Low
M Moderate
H High

4.7.3 Data Gaps and Unresolved Issues

Information about the decomposition rate of chaff casings and components in a range of climatic and ecological conditions is not available. This information is needed to accurately project accumulations in a given area over a period of time, for various levels of use, and to determine what percent of manmade litter would be contributed by chaff training. The extent to which chaff casings and components contribute to litter problems is unresolved. Additional information on amounts of litter collected in varying outdoor settings is needed. If chaff debris is only a minute portion of the litter, it could be concluded that it has little effect on litter problems that could affect user attitudes or use patterns.

The degree to which chaff fibers and debris can be concentrated through wind, runoff, and other natural processes is not quantified. The effects of litter accumulation in stream beds and rivers on aquatic and other wildlife, as well as its noticeability, are unknown. The degree to which chaff fibers and casings are noticeable and may elicit feelings strong enough to change user recreational area preferences is also unknown. Wildlife protection areas within military ranges should be studied for effects on wildlife and, consequently, management objectives for those areas.

An inventory of BLM Class 1 and 2 visual resource areas and Forest Service areas categorized as Preservation, Retention, and Partial Retention should be compiled and mapped. Using a Geographic Information System, it would be simple to identify areas where chaff training activities could affect visual resources.

Field studies are needed to verify the assumed visual contrast rating of chaff debris in various environments (including different terrain, soil color, and ground cover conditions).

4.7.4 Conclusions and Recommendations

4.7.4.1 Land Use

Accumulation of chaff fibers and chaff casing debris is compatible with military use of land owned by the Department of Defense. On the other end of the spectrum, chaff training activity is considered incompatible with Wilderness Areas, Wild and Scenic Rivers, and National Parks and Monuments used heavily for recreation and enjoyment. Chaff training along sensitive coastal zones may not be consistent with management policies, and requires further study.

The accumulation of chaff fibers and casing debris is not anticipated to affect most land uses in rural or remote areas that are not under specific management policies, due to wide dispersion and scarcity of human receptors. Although litter is an annoyance in recreation areas, this debris would probably amount to less than a fraction of the litter in most areas, and it would be imperceptible. However, it is recommended that this determination be field verified, and that more information be gathered from land managers of high and low use recreation areas concerning litter quantities and management. Follow-on research is needed to determine effects of chaff litter on the costs of litter management. Estimates on amounts of litter and cost of litter control and pick up from various agencies and for various visitor use levels would be used to determine the percent of litter that may be contributed by chaff debris in an area.

Field studies are needed to verify visual evidence (noticeability) of chaff in the environment to support assumptions about predicted level of impact on various land uses and specially designated areas. Field studies will also assist in discerning chaff density and related activity levels that can be recommended for various land use categories. It is recommended that both DOD-owned and non-DOD land areas underlying high use chaff training areas be studied. If chaff is evident, then land areas underlying less intensive chaff training areas should be surveyed. Some land use impacts will depend on determinations about the effects of chaff on biological resources.

4.7.4.2 Visual Resources

Chaff fibers and chaff debris are assumed to have a low contrast rating in most environments at low densities (only one chaff object or fiber clump in the range of view at a time). Visual resources with the highest value may not be suitable for any chaff training. This would include Wilderness Areas, Wild and Scenic Rivers, and other Class 1 and Preservation designated areas. Areas with low visual resource quality would not be affected by chaff activities. Areas with Class 2 rating, using the BLM system, would require additional analysis to determine if projected chaff operations would meet contrast standards.

Follow-on field studies are needed to verify contrast ratings for chaff debris. Based on observed conditions, acceptable chaff debris density levels for the different visual resource rankings can be established. If chaff fibers and debris are not evident at all in high-use environments, it may be possible to conclude that there are no visual effects from chaff training. If this is not the case, areas with lower levels of use (current and historic) would be inspected.

Field work would include setting up a system to rate the noticeability of debris at various distances and in various conditions, and to determine what frequency or time between viewing events is acceptable. This research could be used to determine density levels that would be compatible with different visual resource management objectives.

In order to identify chaff training exclusion areas, a list and map of all Forest Service and BLM Preservation/Class 1 visual resources should be compiled. Additional research to identify other areas not managed by these entities that could qualify for similar visual quality ratings should be done. Areas with high visitation and activities involving foreground viewing but with lower visual quality ratings may also be affected. Field studies of conditions in representative Class 2 areas underlying current chaff training areas would assist in determining the noticeability of chaff debris and setting up acceptable density levels for different visual quality categories.

4.8 CULTURAL RESOURCES

Cultural resources are defined as any prehistoric or historic district, site, or building, structure, or object considered important to a culture, subculture, or community for scientific, traditional, religious, or any other reason. The cultural resources discussed in this section include prehistoric and historic archaeological resources, architectural resources, and traditional Native American resources.

Only significant cultural resources warrant consideration with regard to adverse impacts resulting from a proposed action. To be considered significant, archaeological or architectural resources must meet one or more of the criteria (as defined in 36 CFR 60.4) for inclusion on the National Register of Historic Places. There are no legally established criteria for assessing the importance of a traditional Native American resource, although guidance is currently under development. These criteria must be established primarily through consultation with Native Americans according to the requirements of the American Indian Religious Freedom Act and the Native American Graves Protection and Repatriation Act.

Key federal laws and regulations that manage cultural resources include the National Historic Preservation Act of 1966, the National Environmental Policy Act of 1969, the Archaeological and Historic Preservation Act of 1974, the American Indian Religious Freedom Act of 1978, the Archaeological Resources Protection Act of 1979, Executive Order 11593, and the Native American Graves Protection and Repatriation Act of 1990.

4.8.1 Issues Pertaining to Chaff Use

The primary effect of chaff on cultural resources relates to its effect on the aesthetic setting and context of such resources. The potential does exist, however, for the material to physically and chemically impact resources by depositing, accumulating, clumping, decomposing, leaching, and drifting. Factors affecting how chaff is dispersed on the ground include drop altitude, wind direction and velocity, humidity, and release quantities. Because of these conditions, particular effects on cultural resources vary. Chaff may affect cultural resources through the following actions:

- Chaff deposition and accumulation may affect the aesthetic setting and context of cultural resources. However, this applies only to sites where setting is a contributing characteristic of site significance.

- The physical and chemical impact of chaff clumps on archaeological and architectural resources is unknown beyond its effect on the aesthetics of setting and context.

- The decomposition rate for chaff is unknown. Although the effect of decomposition on cultural resources is also unknown, it is likely to be minimal.

- The leaching of chaff into soil may potentially affect traditional plants used by Native Americans. The primary concern is excessive uptake of aluminum by plants.

- Airborne chaff can travel great distances (as much as 20 miles or more) from its point of dispersal, possibly drifting onto architectural resources and Native American communities and traditional food gathering and religious use areas. This can lead to increased deposition and accumulation of chaff on cultural resources.

4.8.2 Summary of Existing Literature/Information

There are no direct studies on the effect of chaff on cultural resources; however, limited studies have been conducted on the physical and chemical effects of the material on natural resources. The effects of chaff on Native American resources, including wildlife, humans, plants, and water, can, in part, be derived by an examination of these studies. Reviews of available data on these issues are included in Sections 4.2, 4.5, and 4.6. As noted in Section 4.6, increased uptake of aluminum by plants is not considered to be a concern.

Chaff is relatively insoluble in water and, depending on individual particle weight, could sink or collect along the shoreline (SAIC 1992). This may present problems for surface feeding wildlife like ducks and for Native American fishermen who could be affected by the aesthetics of the accumulation.

Most studies have not specifically examined the effects of chaff on historic architecture because this type of resource is commonly located away from military training areas. One report (HQ-TAC/DOO 1984) does reference urban areas and concludes no adverse impact to rooftops. However, because airborne chaff can travel as much as 20 miles from its point of dispersal, possibly drifting into urban areas, the potential for impact on the aesthetics of important architectural resources does exist.

No research has been conducted on Native American concerns related to the aesthetics of chaff deposits on the landscape.

4.8.3 Data Gaps and Unresolved Issues

The effects of chaff on the aesthetic setting and context of cultural resources needs to be studied. This can be accomplished in combination with the analysis of accumulation effects on Land Use and Visual Resources (see Section 4.7). A reliable method for predicting chaff dispersal would assist in determining how far from use areas deposition might occur.

Complete information on the physical and chemical effects of chaff on archaeological and architectural resources, including the decomposition rate of the material is lacking. The effects of chaff on wildlife and the biological effects on plants needs further examination because they could potentially be important traditional Native American resources. These issues can be addressed as a byproduct of the research on Physical Resources and Biological Resources.

4.8.4 Conclusions and Recommendations

The primary impact of chaff on cultural resources relates to its effect on the aesthetic setting and context of such resources. The potential may exist, however, for the material to physically and chemically affect resources by depositing, accumulating, clumping, decomposing, leaching, and drifting. In general, the results of research on dispersion and the effects of chaff on physical, biological, and visual resources will be usable to derive conclusions about cultural resources.

Consultation with Native American tribes could also be conducted to determine whether they have any concerns related to chaff use.

5.0 CURRENT DATA ON ENVIRONMENTAL EFFECTS OF FLARES

5.1 ENVIRONMENTAL PATHWAY ANALYSIS

Like chaff, flares are ejected from aircraft into the air. Unlike chaff, flares that perform properly are designed to be consumed (burn out) before reaching the ground. Therefore, the only materials that would be deposited on the Earth's surface are the incidental debris from flare canisters and occasional duds or burning flares. Flares have the potential for raising a number of direct and indirect environmental and safety issues. Figure 5.1-1 presents a graphic depiction of the potential pathways flares and the by-products of their combustion may take in the environment, the various recipients they may affect, and the types of impacts that may result.

Flares may present potential safety risks to aircrews from improper or incomplete ejection. Safety risks to persons on the ground may result from faulty ignition, leading to duds that could be immediately hazardous if they hit someone on descent, or that could remain a potential hazard if picked up later and handled improperly. Burning flares generate air emissions with potential air quality impacts. If a flare is still burning when it hits the ground, it may cause a fire and result in a variety of secondary impacts on soil, water, biological resources, cultural resources, land use, and human safety.

Dud flares and flares that have not been fully consumed are potentially explosive when mixed with water. This raises questions of potential hazards and chemical effects from flares falling into water bodies, as well as resulting impacts on biota. If a dud flare lands on the ground, it may still react with latent moisture or it may remain intact, raising issues of chemical effects on soil and potential indirect impacts on groundwater and vegetation. Wildlife issues include whether light from flares might affect vision. Dud flares and flare debris may accumulate in areas underlying training airspace and result in land use and visual impacts.

5.2 MATERIAL COMPOSITION AND MANUFACTURE

5.2.1 Flares Materials and Containers

Information on flares used by the Air Force was obtained from the Air Logistics Centers at Hill and Warner Robbins AFBs. Published specifications and technical orders were reviewed, and interviews were conducted with Air Force and Tracor personnel.

Self-protection flares are primarily mixtures of magnesium and Teflon (polytetrafluroethylene), molded into rectangular shapes. Longitudinal grooves in this material provide spaces for more sensitive materials that aid in ignition. They include first fire (potassium perchlorate, boron powder, magnesium powder, barium chromate, Viton A or Fluorel binder), intermediate fire (magnesium powder, Teflon, Viton A or Fluorel), and dip coat (magnesium powder, Teflon, Viton A or Fluorel) compositions. The first fire material is applied to grooves on the top of the flare next to the ignitor; the intermediate fire material is applied to side grooves; the dip coat

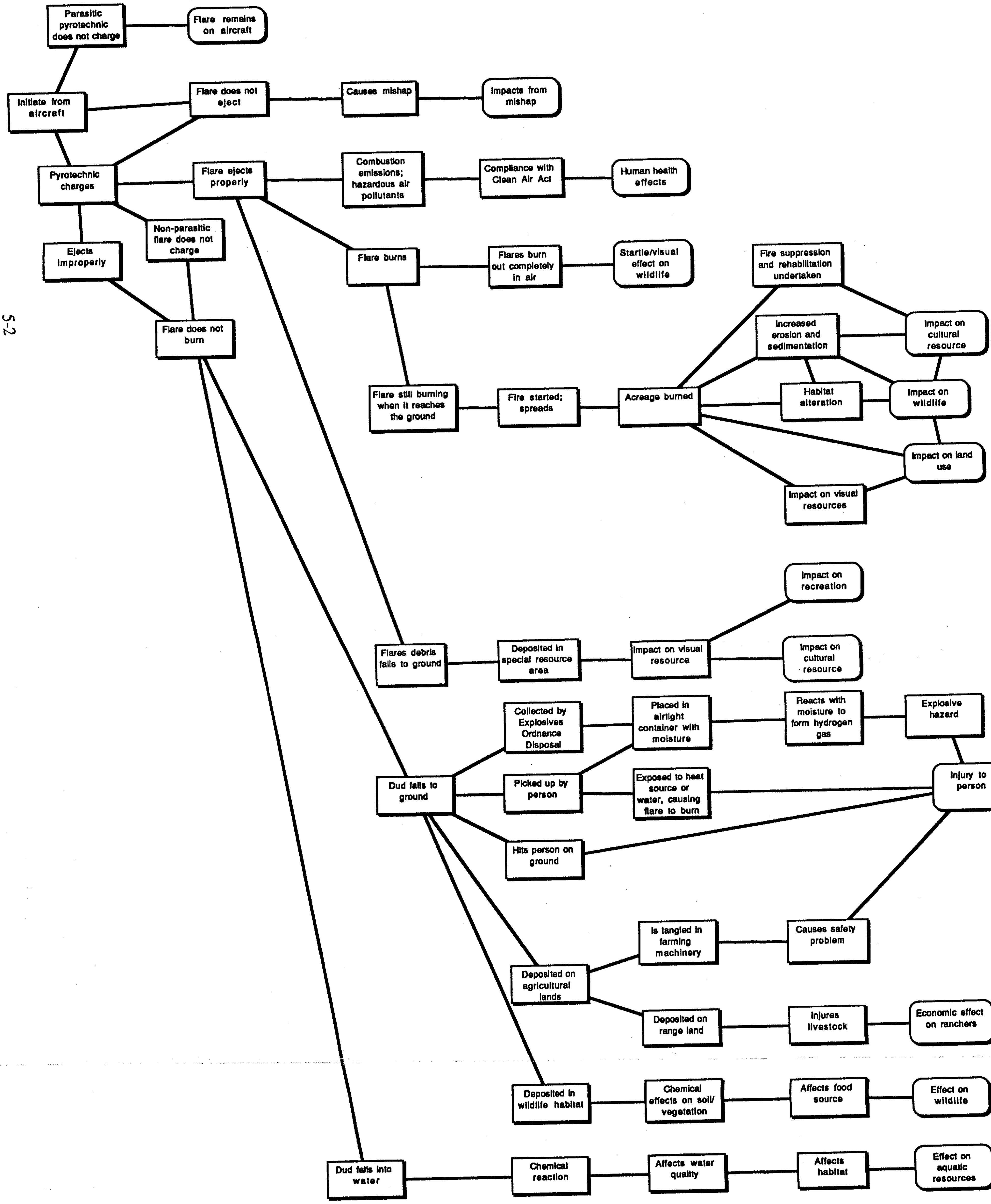


Figure 5.1-1. Flares Pathways into the Environment

is applied to the outer surface of the flare pellet. The purpose of these materials is to provide an ignition path to the main body of the flare, so it will ignite. The most serious hazard from magnesium is danger of burns. It also reacts with water to form hydrogen, a potential fire and explosion hazard.

Flares are wrapped with an aluminum-filament-reinforced tape and inserted into an aluminum (0.03 inches thick) case that is closed with a felt spacer and a small plastic end cap. The top of the case has a pyrotechnic impulse cartridge that is activated electrically to produce hot gases that push a piston, the flare material, and the end cap out of the aircraft into the airstream. Flare composition and expected debris are summarized in Table 5.2-1. Different types of flares differ primarily in their size and the method used for ignition.

When ignited, flares burn for less than 10 seconds at approximately 2,000 degrees Fahrenheit. Combustion products include magnesium oxide and magnesium fluoride. The combustion products from a MJU-10 flare were analyzed in a report by the Tracor Company to the Aeronautical Systems Division (12 July 1978) as follows:

- Magnesium oxide (MgO) -- 551 grams
- Magnesium chloride (MgCl) -- 91 grams
- Carbon (C) -- 41 grams
- Magnesium fluoride (MgF) -- 319 grams

Small quantities of carbon dioxide (CO_2), carbon monoxide (CO), and difluorine oxide were also found. Cartridge residue was analyzed to contain:

- Nitrogen (N) -- 0.1 gram
- CO_2 -- 0.3 gram
- CO -- 0.2 gram
- Water Vapor -- 0.1 gram
- Hydrogen (H_2) -- 0.05 gram

Less than 0.05 gram of boron oxide, potassium oxide, and chromium oxide were also identified. No comparable data were available for other flares.

Table 2.4-2 identifies types of flares used by ACC units and on ACC ranges and airspace. Table 5.2-2 lists those that are in the Air Force inventory, the aircraft that use them, and the estimated annual quantities. The MJU-2 and MJU-8 are Navy flares, and no information on their composition and operation was available. The MJU-33 flare was unknown to buyers at either Hill AFB or Warner Robbins AFB.

Table 5.2-1. Composition and Debris of M-206, MJU-7/B, MJU-7A/B, MJU-10/B Flares

Composition

- polytetrafluoroethylene (teflon)
- magnesium
- fluoroelastomer
  - (viton, fluorel, or hytemp)
- first fire*
  - boron
  - magnesium
  - potassium perchlorate
  - barium chromate
  - fluoroelastomer
- immediate fire and dipcoat
  - magnesium
  - teflon
  - fluoroelastomer

Debris

- Aluminum wrap
  - mylar or filament
  - tape bonded to aluminum tape
- End cap
  - plastic (nylon) except MJU-10 has aluminum end cap
- Felt spacers
  - all are small squares or rectangles 1/4 inch thick with the same areas as the ease cross-section
- Plastic piston
  - nylon, tefzel, zytel
- Slider assembly
  - (MJU-7A/B; MJU-10B)
  - 12 × 3/4 × 2: in two plastic (delrin) pieces with two springs and a roll pin (metal)
- Safety and Initiation Device
  - (MJU-7/B, non-parasitic)
  - G-weight
  - locking bar and fork
  - push button and spring
  - firing pin
  - primer assembly

*MJU-10/B does not have a first fire mix, all the others do.
Source: Ogden Air Logistics Center, Hill AFB, Utah

Table 5.2-2. Flare Quantities and Related Aircraft

Flare	Aircraft	Estimated Annual Use*	ACC Purchase Request**
ALA-17	B-52	4,000	24,000
M-206	A-7, A-10, C-130	420,000	170,000
MJU-7	F-4, F-16, C-130, F-111	400,000	180,000
MJU-10	F-15	40,000	125,000
MJU-23	B-1	1,000	10,000

*Includes Air Force, Reserve, and Air National Guard
**Fiscal year 1994 purchase request. Note that this does not correlate to use and depends on factors such as existing inventory.
Source: Ogden Air Logistics Center, Hill AFB, Utah

The ALA-17A/B flares consist of two aluminum cylinders, each 4.75 inches long and 2.25 inches in diameter, crimped together end-to-end. They are fired independently, with the entire bottom cylinder being ejected from the aircraft. When the top cylinder is fired, only the flare pellet is ejected. Impulse cartridges are not used; the flares are fired directly with an electrically-activated squib set in potting compound. Debris includes the entire bottom cylinder assembly and the end cap and felt spacers from the top flare.

The MJU-7/B and A/B flare configuration is shown in Figure 5.2-1. All versions of this flare are 1 by 2 by 8 inches and have a nominal weight of 10 ounces. They use a BBU-36/B impulse cartridge (Table 5.2-3). There are two versions of the MJU-7/B: a "parasitic" and a "non-parasitic" type. The parasitic type is ignited in the aluminum case shortly before it leaves the aircraft by holes in the piston that permit ignitor gases to contact the first fire mixture on top of the flare pellet.

The non-parasitic type flare incorporates a mechanical mechanism (a safety and initiation device) to prevent initial ignition of the pellet in the case. This mechanism includes a G-weight, a locking bar and fork, a push button and spring, a firing pin, and primer assembly. When ignited by the firing pin, the primer assembly fires the ignition charge (15 mg of basic lead styphnate, lead azide, barium nitrate, antimony trisulfide, and tetracene) which fires the output charge (40 mg of zirconium, molybdenum trioxide, potassium perchlorate) which ignites the flare pellet.

The MJU-7A/B was designed to reduce the complexity of the non-parasitic type flare, improve its reliability, and reduce debris (Figure 5.2-2). In this flare, the mechanical mechanism is replaced with a slider assembly that incorporates an initiation pellet (640 mg of magnesium, teflon, Viton A or Fluorel binder). This pellet is ignited by the impulse cartridge, but its hot

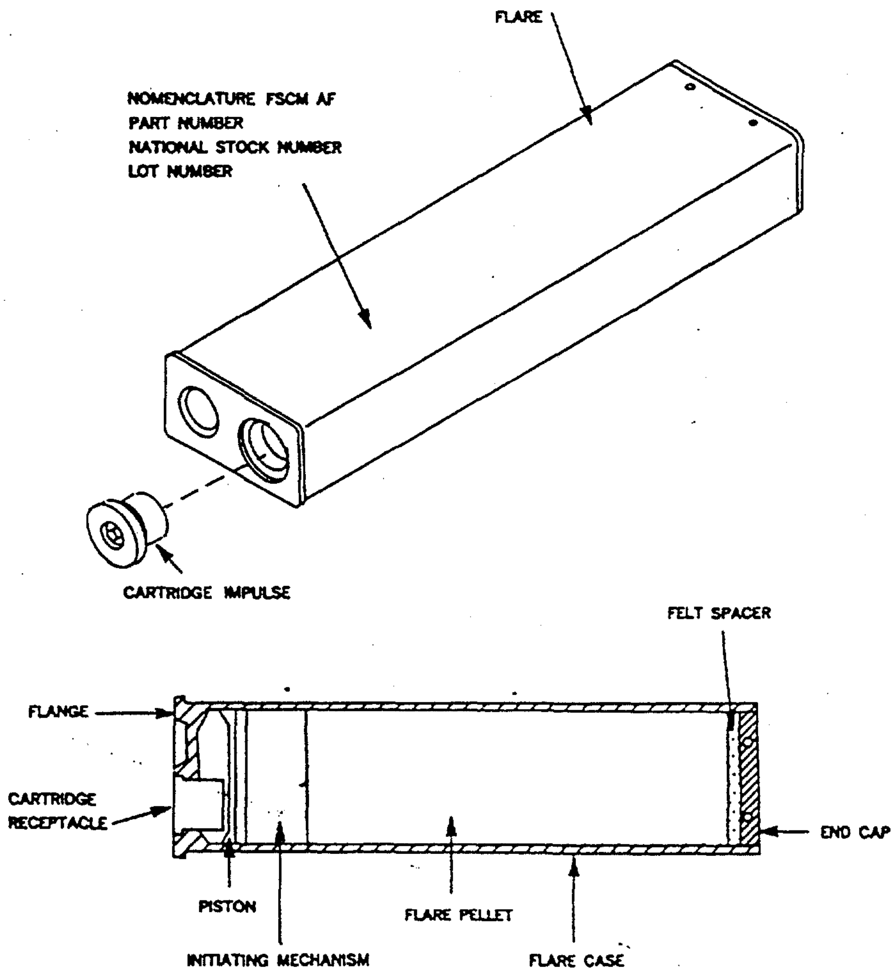


Figure 5.2-1. MJU-7B and MJU-7A/B Infrared Flare

Table 5.2-3. Impulse Cartridges Used With Flare Units

Size	BBU-36/B	BBU-46/B	M796
Overall	.740d × .550in 0.236 (in^3)	1.224d × .520in 0.612 (in^3)	.449 × .530 0.104 (in^3)
all explosive	0.081 (in^3)	0.294 (in^3)	0.033 (in^3)
Initiation	(.358d × .200)/2 0.010 (in^3)	.375d × .150 0.017 (in^3)	(0.348d × .35)/3 0.011 (in^3)
Booster	(.358d × .200)/2 0.010 (in^3)	1.144d × .270/2 0.138 (in^3)	(.348d × .35)/3 0.011 (in^3)
Main charge	.625d × .200 0.061 (in^3)	1.144d × .270/2 0.138 (in^3)	(.348d × .35)/3 0.011 (in^3)
BRIDGEWIRE	Tophet A	Tophet A comp. E	Tophet A 0.0025 dia
DISC	scribed disc, washer	polyester film disc and plain discs for main charge and initiator	scribed disc, washer
INITIATION CHARGE	100 mg 6200 psi boron 42.5% potassium perchlorate 52.5% Viton A 5.0%	to fill cavity 5100 psi potassium perchlorate 49.5% titanium with potassium dichromate 49.5% Viton A or Fluorel 1.0%	100 mg 5500 psi boron 20.0% 1.0 micron calcium chromate 80.0% 3.0 micron
BOOSTER CHARGE	150 mg 5100 psi boron 20% 1.0 micron potassium nitrate 80% binder 3% may be added	290 mg loose fill with main charge boron 23.7% potassium nitrate 70.3% 15 microns laminac binder 5.9% catalyst 0.1%	70 mg 5500 psi boron 18.0% 1.0 micron potassium nitrate 82.0% 15 microns
MAIN CHARGE	655 mg loose fill #2400 smokeless powder Hercules*	490 mg loose fill green dot powder Hercules	185 mg loose fill HPC-1 (Dwg 10534810) Hercules (~40% nitrocellulose)

Source: Air Logistics Center, Hill AFB, Utah
*Hercules smokeless powder contains nitrocellulose (50-77 percent) and nitroglycerine (15-43 percent)

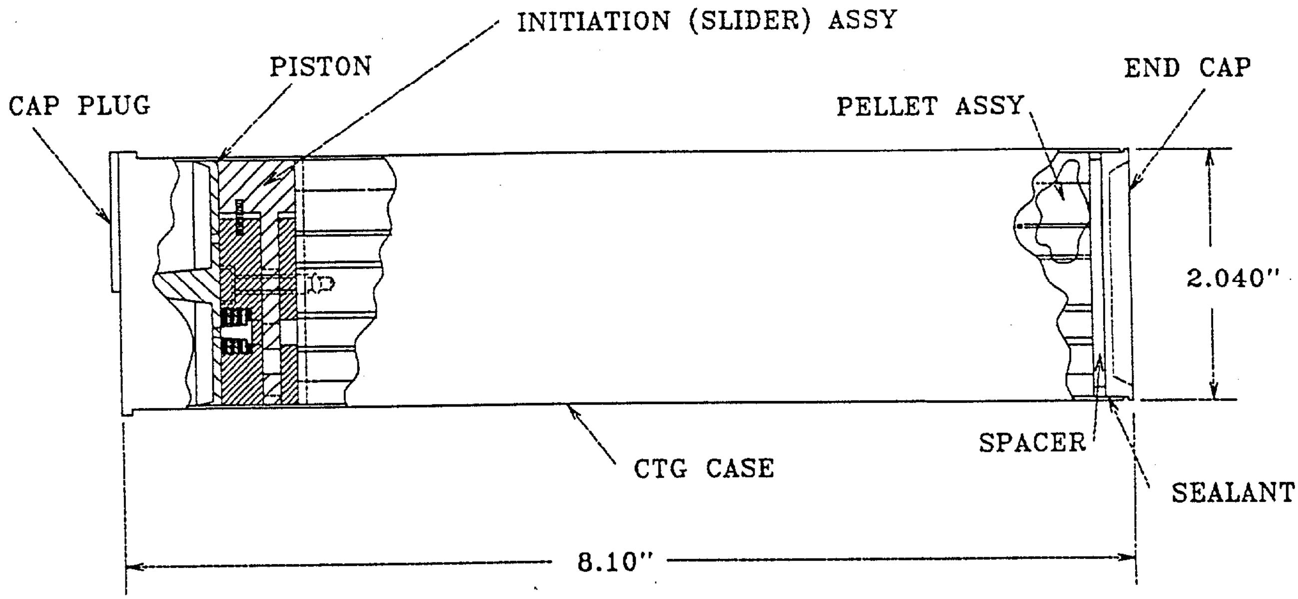


Figure 5.2-2. MJU-7 A/B Flare Assembly

gases do not reach the flare until the slider exits the case, exposing a fire passage from the initiation pellet to the first fire mixture on top of the flare pellet.

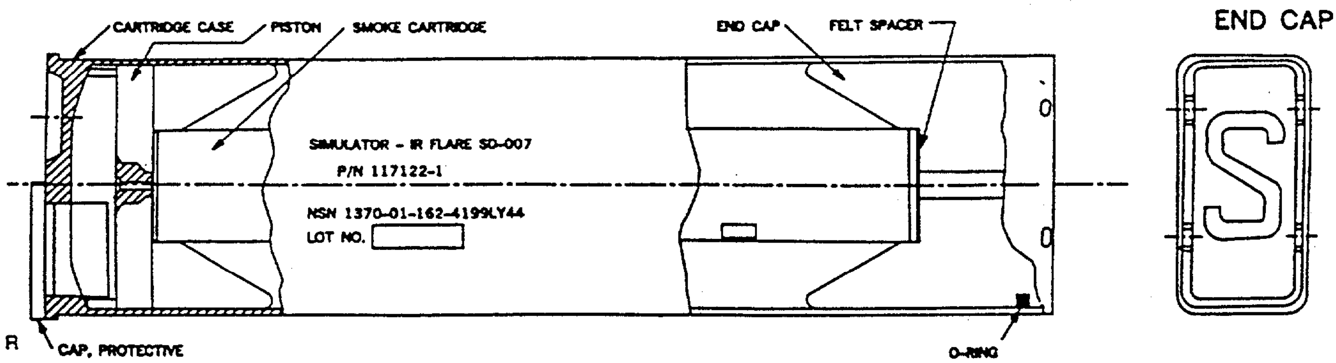
The parasitic type flare is less likely to produce duds, and the only debris is the plastic end cap and the remains of the piston. However, there is an increased risk of some fire damage to the aircraft, compared with the non-parasitic flare. The non-parasitic type flare can be expected to produce the largest number of duds and the most debris, due to the complexity of the flare ignition process. The MJU-7A/B provides a middle ground by igniting a small pellet inside the case, rather than the flare itself, thereby reducing both the safety risk and the quantity of debris. Since the complexity of the flare ignition process of the MJU-7A/B falls between the parasitic and non-parasitic versions of the MJU-7/B, the dud rate can also be expected to fall between them.

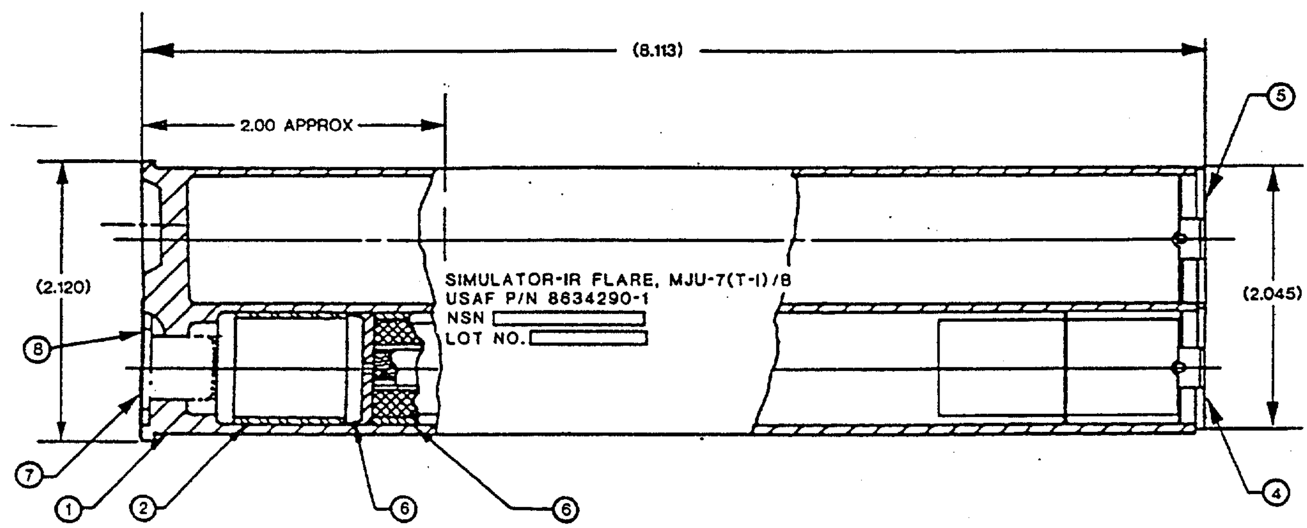
The MJU-7(T-1) (Figure 5.2-3) is a simulator version of the MJU-7/B. It replaces the magnesium flare pellet with a smoke charge. The smoke charge is smaller than a flare (5 inches long vs. 8 inches) and is held in place inside the flare case by cardboard spacers. It is composed of doughnut-shaped pellets 0.75 inches in diameter with a 0.37 inch hole, 0.5 inches thick, encased in a cardboard tube. The charge material is 20 percent powdered sugar, 36 percent potassium chlorate, 42 percent yellow dye (Chinoline Yellow-5), and 2 percent binder (Goodrich Hightemp, a dry rubber, and teflon). It uses the M-796 impulse cartridge which generates hot gases that push the piston down the case and simultaneously ignite a Quick Match cord (MIL-Q-378) in the center of the pellets. Debris includes the remains of the cardboard spacers and piston and the plastic end cap.

The M-206 flare is the same length as the MJU-7 (8 inches), but half the cross-section (1 by 1 inch) (Figure 5.2-4). It uses a M-796 impulse cartridge that ignites the first fire mix simultaneously. The M-206 (T-1) is the simulator version of the flare.

The MJU-10/B configuration is identical to the MJU-7A/B (containing the slider assembly), except the MJU-10/B is thicker (2.66 inches vs. 1 inch), and it does not have a first fire mix (Figure 5.2-5). (The first fire mix is also being eliminated in the MJU-7 to provide increased contractor safety and reduce cost.) The MJU-10/B uses the BBU-36/B impulse cartridge. There is also a simulator version, the MJU-10 (T-1), which uses the M-796 cartridge.

The MJU-23 is a cylindrical flare used in small quantities on the B-1 aircraft (Figure 5.2-6). It is 10.5 inches long and 2.75 inches in diameter. It includes the same complex safety and initiation device as the non-parasitic version of the MJU-7/B. It has an aluminum end cap with 0.5 inches of black rubber potting compound designed to absorb the shock of hitting spring-loaded doors on the aircraft. It also uses an aluminum piston and includes felt spacers in strips on the side and circular shapes in the cylinder. The design is being simplified to reduce the relatively large quantity of debris. The MJU-23 uses the BBU-46/B impulse cartridge.





	8	COVER
	7	CARTRIDGE, IMPLS.
	6	CARTRIDGE ASSY.
	5	PLUG
	4	END CAP
	3	PISTON
	2	SPACER
	1	CASE-MJU-7(TI)/B

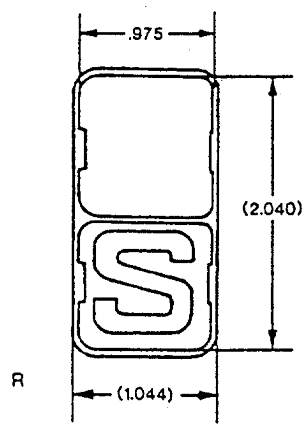


Figure 5.2-3. Simulator Infrared Flare MJU-7(T-1)/B

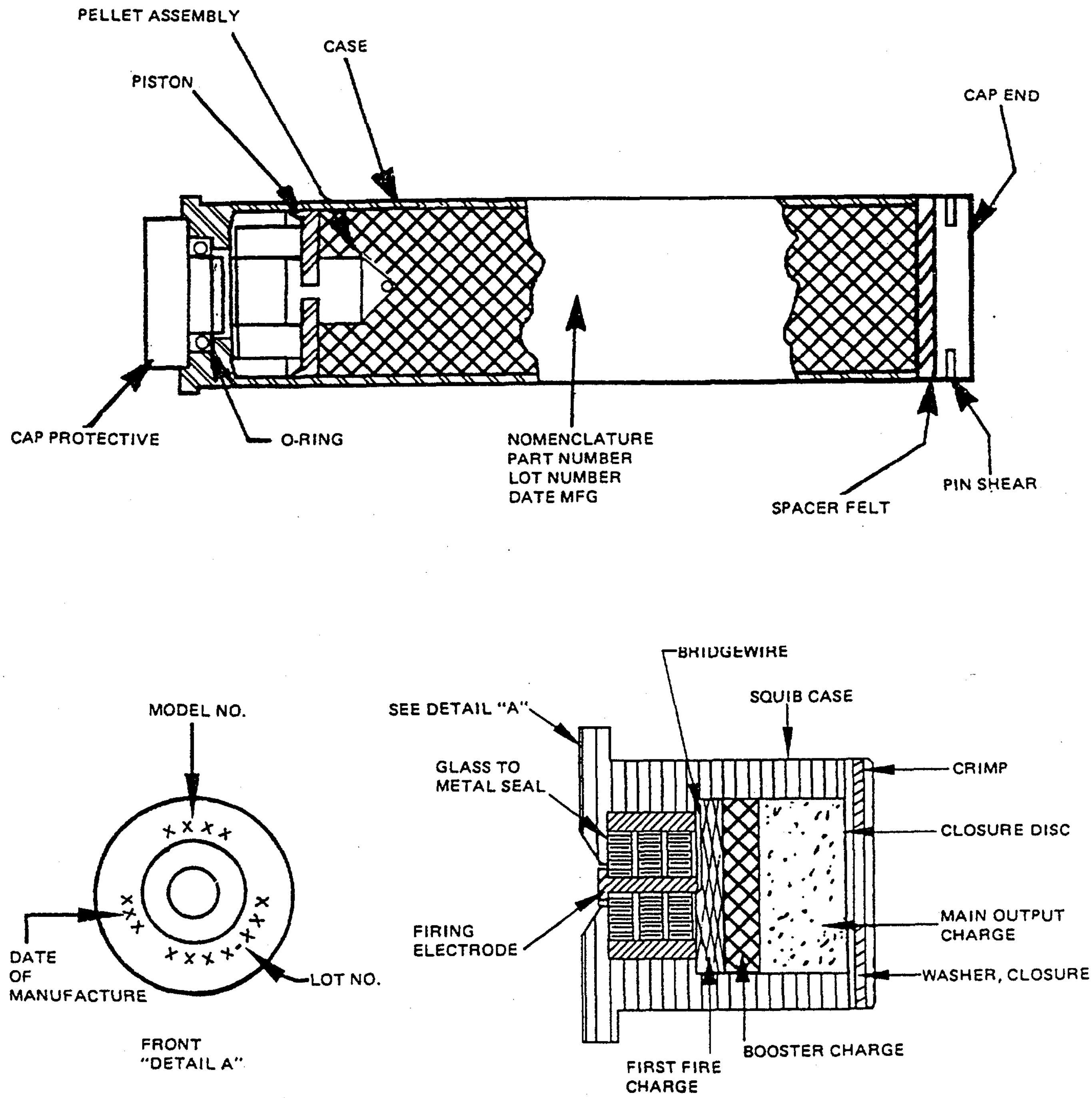


Figure 5.2-4. M-206 Flare and M-796 Impulse Cartridge

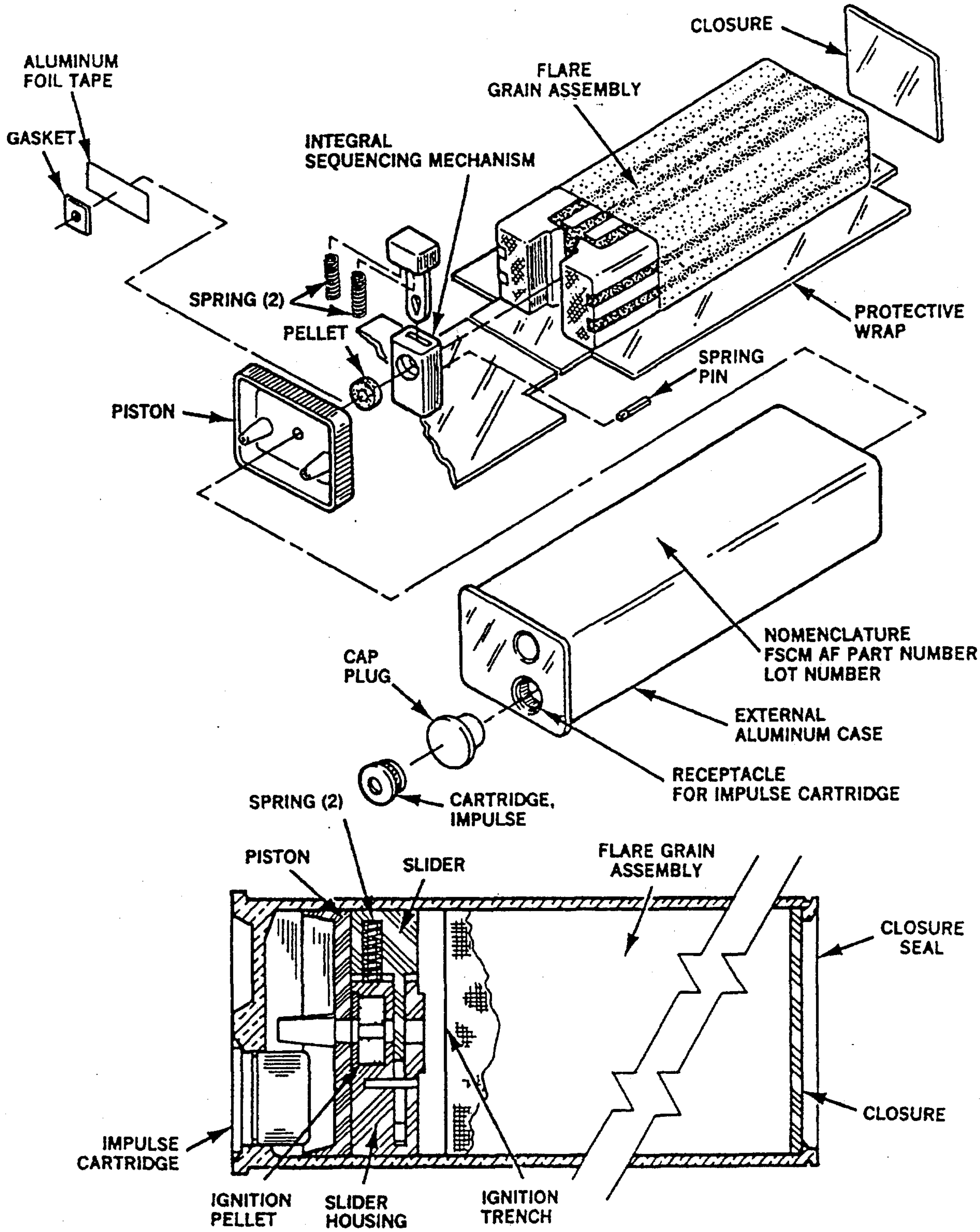


Figure 5.2-5. MJU-10/B Infrared Flare

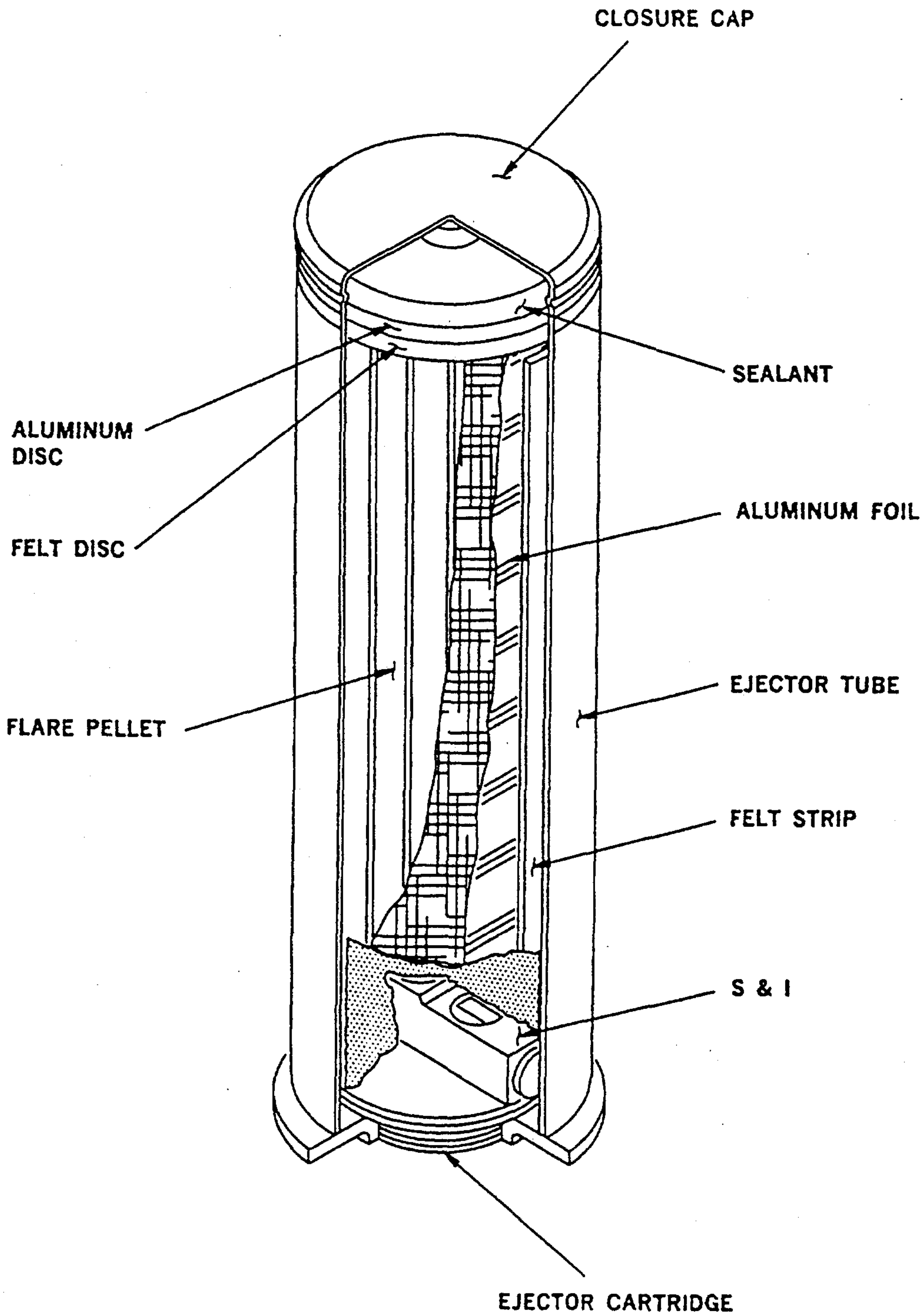


Figure 5.2-6. MJU-23/B Infrared Flare

Flares are tested to insure they meet performance requirements in terms of ejection, ignition, and effective radiant intensity. For example, radiant intensity for the MJU-7A/B must reach 8 kilowatts per steradian in the 3-4 micron band within 16 milliseconds. They must also meet the following conditions before performance testing:

- Temperature — 65 to 250 degrees Fahrenheit.
- Altitude — sea level to 35,000 feet.
- Humidity — up to 100 percent.
- Shock — test specified in MIL-STD-810B.
- Vibration — test specified in MIL-STD-810B.
- Crash Safety — load factors of 40 Gs longitudinal, 20 Gs vertical, 11 Gs in any direction.
- Drop Test — free-fall from 20 feet to hard surface.

After these tests are conducted, the units must demonstrate a reliability of 95 percent at a 95 percent confidence level.

5.2.2 Toxicity of Flares

The primary components of flare combustion are magnesium oxide, magnesium chloride, and magnesium fluoride. Review of the HMDB database revealed that magnesium oxide produces moderate toxic effect and that probable oral lethal dose in humans is estimated to be between one ounce to one pound for an average 150 pound individual. Magnesium oxide is often found in diet; the compound is widely taken as an antacid or cathartics. Occupational exposure studies have shown that MgO dust may cause metal fume fever (HSDB 1993(a)). Magnesium chloride is a naturally occurring salt. One study indicated that normal kidney functions can readily excrete magnesium ions after oral ingestion (HSDB 1993(b)). This surmises that magnesium ions are not readily absorbed into the body through the intestine. Sufficient evidence is currently not available to assess the toxic effects of magnesium fluoride. The Occupational Safety and Health Administration (OSHA) standard for worker exposure for an 8-hour time weighted average is 2.5 milligrams per cubic meter of air.

Acute magnesium toxicity studies in mammals show it to cause nausea and cardiovascular and central nervous disorders (HSDB 1993(a)). Additional mammalian studies showed that magnesium oxide is not readily excreted from the body and has the propensity to remain in the body for longer periods of time. Magnesium has been shown to be retained in skeletal, muscular, and soft tissues. Supplementary studies indicated that magnesium is an essential nutrient often found in nuts, seafood, and cereals. Deficiency in magnesium is known to cause neuromuscular irritability, cardiac and renal damage, and calcification. In summary, it is difficult to assess the actual toxicity impact of the quantity of magnesium compounds found in the flare combustion process. This is primarily due to the inability to determine how much of the actual compounds a particular species might be exposed to.

Another component of flares is oxygen difluorine. This compound is used in general as an oxidant in missile propellant systems. It is usually in a gaseous phase and is incompatible with numerous materials including metal oxides and moist air. Potential routes of exposure can occur via inhalation and dermal contact. Toxic health effects may include pulmonary edema, respiratory system irritation, and skin and eye burns (Sittig 1985).

Some of the initiator cartridges used with flares contain chromium or lead compounds. Toxicological information on chromium and lead is provided in Appendix E.

5.2.3 Flares Reaction with Water

The principal component of flares is magnesium, which reacts with water to form magnesium oxide and hydrogen. In an open environment, hydrogen dissipates quickly, but in a closed environment, it can create a fire and explosion hazard. For example, there was an incident at McDill AFB where unburned flares were received from the field and placed in barrier bags. These bags have a layer of aluminum foil sandwiched between polyethylene and polypropelene. When the bags puffed up, one was opened with a knife, creating an electrostatic charge that ignited five flares (Bullock, personal communication, 1993).

This incident suggests that it is not necessary for the flares to be in direct contact with water to generate hydrogen. Moisture picked up in field conditions is apparently adequate to generate an explosive mixture in a sealed container. This indicates that flare duds that are picked up on ranges during debris removal operations should not be placed in sealed containers or closed environments before disposal.

5.3 SAFETY

Self-protection flares are deployed by ACC aircraft to mislead or confuse heat-sensitive or heat seeking anti-aircraft systems. Their effective use in combat requires frequent training by both aircrews and ground support crews. The training must simulate battle conditions (altitudes, maneuvers, terrain, and flight parameters) to be most effective. This requirement, coupled with the reliability of the flare combustion and deployment systems, results in infrequent but predictable safety events.

5.3.1 Safety Issues Pertaining to Flare Use

This section describes Air Force safety experience with flares and identifies a set of operational events that may result in impacts to the safety of ACC air and ground crews, the general public, and the environment. The consequences of these events are described in subsections 5.4 through 5.9. Where possible, a probability of occurrence of each postulated operational event is identified based on Air Force experience with the current self-protection flare systems. The general issues of concern are:

- Flares malfunctioning within aircraft, jeopardizing the aircraft and its crew.
- Flares igniting wildfires.
- Flares or other debris hitting a person on the ground.
- Accidents and injuries from dud flares.
- Dud flares mixing with water to create a potential explosive hazard.

5.3.2 Summary of Existing Literature/Information

Many studies and reports have assessed the potential impacts, consequences, and accidents resulting from flare use. A wide range of sources were accessed to provide as diverse and comprehensive a search as possible. The databases consulted are shown in Appendix B. Non-DOD sources have not been contacted. It should be noted that while a number of reports and studies exist, no formal safety analyses of the flare system (SAR or PRA documents) could be found in any of the sources.

5.3.2.1 Historic Mishaps

ACC currently uses approximately 356,000 flares per year on the ranges and other special use airspace (see Table 2.4-2). The most comprehensive data concerning mishaps was received from Headquarters Air Force Safety Agency, the Air Force Directorate of Nuclear Surety, and Headquarters Air Combat Command Explosives Safety Section. Headquarters Air Force Safety Agency, prior to implementing a new computer database program on March 1, 1993, maintained mishap data for 17 years. Under the new system, data is only maintained for 10 years. Some pre-1983 data is available and will be referenced. Air Force definitions for mishap categories and classes are found in AFR 127-4 and summarized in Section 4.3.2 and Appendix F.

From January 1983 to February 1993, the Air Force experienced 156 Ground Mishap category incidents involving flares (Table 5.3-1). There were no Class A mishaps, two Class B mishaps, 21 Class C mishaps, 26 Class D mishaps, and 107 High Accident Potential mishaps. These incidents occurred primarily during removal of flares from, or return to, storage; routine maintenance and inspection; droppage; and bench testing/troubleshooting of flare systems.

Flare duds would be expected to represent less than 5 percent of all flares deployed (see Section 5.2). However, the small number of duds at the Nellis Range (50) between 1988 and 1991 (SAIC 1991) suggests the actual dud rate may be smaller. While one case of personal injury from a flare dud was documented, no documentation on fires from flare duds could be located. Flares dropped

Table 5.3-1. Ground Mishap Category Incidents Involving Flares, 1983-93

Hazard Class	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
B		1			1						
C	3	7		1	5	2		1	1	1	
D				1	2	1	1	5	12	4	
Other*	12	13	20	22	16	10	9	3	2		
*High Accident Potential											

from below 500 feet AGL were a cause of fires at Nellis Range between 1987 and 1989. The most significant fire was in 1987, burning 35,000 acres and costing $130,000 to extinguish (SAIC 1991).

While there were no Flight or Flight-Related Aircraft Mishaps involving Class A, B, or C mishaps during flight operations from January 1983 to February 1993, one Class A mishap did occur in 1980 involving an F-102G. The aircraft was on a target profile mission in the AIM-9M Missile Test Project. The aircraft was configured with ALE-28 flare dispensers and RR-119 flares. The pilot was forced to eject from the aircraft. He suffered a major injury, and the aircraft was completely destroyed.

There were no Class A or B mishaps, three Class C mishaps, and 101 High Accident Potential mishaps in the Aircraft Involvement category (Table 5.3-2). The Class D mishap class category is not used in conjunction with aircraft categories. These incidents resulted in no fatalities or permanent physical disability.

Table 5.3-2. Aircraft Involvement Category Involving Flares, 1983-93

Hazard Class	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
C			1		1			1			
Other*	9	14	13	19	14	6	9	6	7	4	
*High Accident Potential											

5.3.2.2 Flare System Safety Risks

The analysis of system safety risks from flares is based on AFR 127-4; the methodology is described in Section 4.3.2.2. For the purposes of this analysis, historic mishap data and postulated accidents have been grouped into six events. These events and their potential results are described in Table 5.3-3. They include dud flares, hung flares, and other low probability operational events (long and short ignition periods, low and high altitude operations, early and late ignition of flare). The results of these events range from no effect or concern to the loss of aircraft and ignition of wildfires. The size of potential fires is not factored into the safety analysis, but is addressed in Section 5.4.

The postulated consequences of the system safety events with effects of concern are those with substantial loss of environmental resource (from fire) or human health. The effects of concern and the expected (or historic) probability are listed in Table 5.3-4.

5.3.2.3 Consequences of System Safety Events

Based on the available data, aircraft and non-aircraft mishaps were evaluated using the severity and probability categories described above. Table 5.3-5 summarizes the Air Force-wide flare mishap data from 1983 to 1992.

By combining the historic mishap probability information from Table 5.3-5 with the postulated system safety events, hazard evaluations for the events of concern were developed (Table 5.3-6). Based on these classifications, all events are within the Acceptable range, except for the injury to ground personnel from a dud flare mishap. This event falls within the Undesirable range. Historic data shows that this event occurs several times per year.

Flare debris includes end caps, pieces of safety and initiation devices, and duds that may be ejected but not ignited. When ejected from altitudes above 500 feet AGL, the debris will decelerate to terminal velocity before hitting the ground. This velocity can be calculated using the following equation:

$$V_T = \left[\frac{2}{\rho}\left(\frac{W}{AC_D}\right)\right]^{1/2}$$

where

V_T = Terminal velocity
ρ = Air density
W = Weight
A = Surface area facing the airstream
C_D = Drag coefficient

Using sea level density of 2.378×10^{-3} lbs-sec^2/ft^4 and the flat plate drag coefficient of 1.28, terminal velocity and momentum can be calculated for various debris items, shown in Table 5.3-7.

Table 5.3-3. Description of Flare Design-Based Accidents

Event	Description	Consequence
A	Dud Flare Released from Aircraft a) does not hit anything b) hits person	1) Flare does not ignite 2) Flare ignites on the ground a) Does not start wildfire b) Ignites wildfire
B	Dud Flare "Hung" on Aircraft	1) Retrieved in post-mission check-out without incident 2) Retrieved in post-mission check-out with injury to crew or damage to aircraft
C	Flare Ignites Too Early	1) Causes fire on aircraft resulting in loss of aircraft a) Causes no fire on ground b) Causes wildfire 2) Causes fire on aircraft resulting in minor damage
D	Flare Ignition Delayed/Long Burning Flare	1) Aircraft altitude sufficiently high a) Flare burns out prior to contacting the ground 2) Aircraft at low altitude a) Flare burns out prior to contacting the ground b) Flare is burning on ground contact and does not result in wildfire c) Flare is burning on ground contact and does result in wildfire
E	Short Burning Flare	Flare burns out prior to contact the ground
F	Broken Flare (either at ejection or during burn period)	1) Flare burning at ground contact 2) Flare extinguished at ground contact
G	Flare debris hits person on ground	

Table 5.3-4. Postulated Consequences of Flares Safety Events

Event	Probability (per use)	Result
A (1a)	5%	Leachable chemicals and litter
A (1b)	*	Physical injury or facility damage
A (2b)	*	Ignites fire
B (2)	1/30,000	Ground crew injury, aircraft damage
C (1a)	1/5,000,000	Loss of aircraft
C (1b)	(1)	Loss of aircraft and ignites fire
C (2)	1/170,000	Damage to aircraft
D (2c)	(1)	Ignites fire
F (1)	(1)	Ignites fire
G	*	Physical injury
* insufficient data		

Table 5.3-5. History Summary (Flares)

Events/Severity (Mishap Class)	Probability (Hazard level)*	
	Non-Aircraft	Aircraft
1 Catastrophic (A)	0 (E)	2×10^{-7} (E)
2 Critical (B)	5×10^{-7} (E)	(E)**
3 Marginal (C)	6×10^{-6} (E)	8×10^{-7} (E)
4 Negligible (High Accident Potential)	3×10^{-5} (D)	3×10^{-5} (D)
*Based on estimated annual ACC use of 356,000 flares/year as reflected in Table 2.4-2 **No events recorded		

Table 5.3-6. Expected Hazard Evaluation of Safety Events of Concern

Event	Severity Index	Probability Index	Hazard Risk Index	Rating-Action Required
A(1a)	4	A	4, A	Acceptable
A(1b)	1	E	1, E	Acceptable
B(2)	3	D	3, D	Undesirable
C(1a)	1	E	1, E	Acceptable
C(1b)	1	E	1, E	Acceptable
C(2)	2	E	2, E	Acceptable
G	4	D	4, E	Acceptable
Note: A (2b), C(1b), D(2c), and F(1) are not evaluated since their severity is dependent on specific location and size of the fire event.				

Table 5.3-7. Terminal Velocity and Momentum of Flare Debris

	Terminal Velocity		Momentum (mV_T)
	feet/sec	miles/hr	pound-seconds
MJU-10 Dud	210	143	16.27
MJU-7 Dud	197	134	4.99
M-206 Dud	208	142	2.78
MJU-7 Slider	78	53	0.068
MJU-7 End Cap	21	14	0.00613

Laboratory experimentation in accident pathology indicates a 90 percent probability of brain concussions resulting from an impulse of 0.70 pound-seconds and less than 1 percent probability from impulses less than 0.10 pound-seconds (Ommaya 1968).

The momentum values for the duds are equivalent to the impact of an eight pound sledge hammer dropped from a height of 67 feet for the MJU-10, 6 feet for the MJU-7, and 2 feet for the M-206. These energy levels could be expected to result in severe injuries or death in humans.

It is highly unlikely, however, that injuries would result from impact of sliders and end caps, which would have a momentum value of less than 0.10 pound-seconds at terminal velocity.

5.3.3 Data Gaps and Unresolved Issues

Several informational sources are forwarding additional materials. Additional technical reports from the computer database bibliographies have been ordered. Applicable references in existing literature are being collected. As these date become available they will be incorporated into this analysis.

A number of the personnel contacted made reference to flare-initiated fires at Nellis Range. Headquarters Air Force Safety Center advised they have no record of any range fires, and it is probable that they were not reported as mishaps. A number of flare-related fires between 1987 and 1989 occurred at Nellis Range (SAIC 1991). Nellis Range personnel and the Bureau of Land Management need to be contacted for follow-up data on these fires.

Several studies and reports have been undertaken over the years regarding the safety of flare use. Each seems to capture a "snapshot" of the potential and probable impacts that flare use has on human health and safety. No long-term studies of the progressive effects of flares exist. This type of data will be necessary for any comprehensive assessment of flare use.

5.3.4 Conclusions and Recommendations

The data reviewed to date indicate that flares pose no significant threat to safety. The mishap data show that, with the one Class A exception, relatively few, mostly minor, accidents have occurred over the last 17 years. When mishaps did occur, they were confined mainly to Air Force personnel and property. Civilian impacts were found to be minimal or non-existent. Further information needs to be collected on fire risks from flares. This is addressed in the next section.

5.4 FIRE HAZARDS

5.4.1 Issues Pertaining to Flare Use

Avoidance of impacts on people, livestock, and other resources is a consideration in the selection of areas for training in air operations, so only incidentally are fire starts even possible under planned training operations. Minimum ground clearance levels for the dispensing of flares are established to reduce the possibility of unwanted effects on the ground. Minimum release altitudes for flares are specified to provide for complete combustion and consumption.

Except in areas where there is no fire risk, it is assumed that all training activity involving flares is conducted at or above altitudes that ensure the flares will be completely consumed in the air, if they operate properly. This is consistent with AFR 55-79. Based on this assumption, fires from flares will be rare, resulting from the flare not performing properly or from inadvertent aircrew error. This conclusion is generally substantiated by the lack of data on flare-related fires. The probability of improper performance or inadvertent error in an area susceptible to both fire ignition and spread is very low and probably cannot be predicted to any level of statistical significance. Nevertheless, flare-ignited fires can occur, and a level of risk does exist.

There are several reasons that a burning self-protection flare could reach the ground:

- The flare could be released at too low an altitude with inadequate surface clearance.

- The flare could descend unexpectedly rapidly due to vertical shear or wind burst.

- The flare could burn at an unexpectedly slow rate due to manufacture error.

- The igniter could malfunction, causing the flare to ignite late in the air or fall to the ground as a dud and ignite later.

- The flare could land on a dead tree top while still burning.

The analysis in this section focuses on predicting the probability of a fire, if it starts, resulting in significant adverse impacts, rather than the probability of a fire starting. It is recommended that operational procedures also be based primarily on the risk of a fire spreading and impacting the environment, rather than on the probability of a burning flare reaching the ground. The former is probably reasonably predictable, while the latter is not.

Given that training with flares is conducted on ranges and in special use airspace in relatively remote areas, fires could be ignited in rural or remote areas. Fires from flares in dense residential or urban areas are not considered an issue. Therefore, any fires that might occur are likely to be on agricultural lands or uninhabited forest or rangelands.

The effects of fires can be classified as immediate, delayed, and long-term and further according to the whether the effects are felt on site or off site. Following are the most common potential adverse effects:

- Immediate fire effects

  — Destruction of surface vegetation.

- Morbidity and mortality of standing shrubs and trees.
- Demise of insects, small animals, and eggs.
- Effects on seeds, spores, and microbes in duff and soil.
- Temporary disruption of local surface travel, both by animals and humans.
- Smoke generation.

- Delayed fire effects

  - Altered mineral nutrient levels and soil pH.
  - Altered suitability of site to invasion by offsite vegetation.
  - Increase in site vulnerability to wind and water erosion.
  - Changed surface water runoff quantity and content of water, including effects on aquatic biota downstream.
  - Loss of food and/or shelter for local and migratory wildlife.
  - Altered vulnerability to opportunistic insects and diseases.

- Long-term fire effects

  - Changes in landscape, with concomitant changes in patterns of land use by animals and humans.
  - Long-term changes in the distribution of plant community species.
  - Loss of critical habitat for threatened or endangered species.
  - Changed productivity patterns due to topsoil transport.
  - Permanent landform alteration by erosion.

Some of these effects are restricted to the burned site, some affect adjacent lands, and some have geographically extensive implications. Some of these effects can be beneficial from one perspective but detrimental from another, and some may vary in importance depending on the location and social or economic circumstances. In short, the potential impacts of unwanted fires are so variable with location, season, and circumstance that a thorough analysis can only be undertaken on a site-specific basis.

In general, the impacts on environmental resources from unwanted fires are well documented and do not depend on the cause of the fire. It is recognized that they can be significant. Since they are not unique to flare-caused fires and are secondary to the assessment of risks associated with flare use, this report does not provide an in-depth analysis of the potential consequences of fire. Instead, the focus is on determining the potential for a fire starting, spreading, and thereby resulting in some significant level of impact. In order for a fire to have any impact at all, it must spread from its point of origin. In most cases, a fire that burns only a few square yards, however undesirable, will have an insignificant impact compared to one that burns thousands of acres.

5.4.2 Summary of Existing Literature/Information

Except for the antarctic, the hot deserts, and tropical wetlands, fire is one of the components of the natural ecosystem. In the climatic zones classified as Mediterranean, fire may be the dominant natural force maintaining the system, and it is a major force in all the arid temperate, boreal, and austral zones. The more fire-prone an ecosystem, the greater the role of natural fire in shaping the ecosystem. However, although fire is a natural part of the evolution of these areas, fires caused by artificial means are not. While a fire may reinvigorate the growth of grasses and diminish the relative abundance of undesirable species present, the loss of fodder in the field may impose an economic burden on the range user if the fire was not planned. Therefore, any unplanned, uncontrolled fire is considered undesirable if it was caused by other than natural processes.

Resources for studying potential effects of unwanted fires include, in addition to the extensive scientific literature on fire effects, two databases specifically designed to aid in the planning of prescribed fires and devising landscape and ecosystem scale fire management plans. One is the bibliographic data base maintained by the International Association of Wildland Fire in Fairfield, Washington, which is supported by USDA Forest Service, the BLM, and the National Park Service. The second is the automated Fire Effects Information System developed and maintained by the Intermountain Fire Sciences Laboratory (IFSL), USDA Forest Service, Intermountain Forest and Range Experiment Station in Missoula, Montana. This database is available agency-wide and to other federal land management agencies and their contractors and cooperators. It replaced the defunct FIREBASE automated literature data base that had been maintained by the Boise Interagency Fire Center in Boise, Idaho, and contains up-to-the-minute research findings.

5.4.2.1 Igniting a Fire

Very little has been done in the way of assessing the probability of ignition of a wildland fire by a single source (such as a flare). Since there can be such an abundance of ignition sources, the probability of a single source becomes irrelevant to fire management. One study performed at the USDA Forest Service, Riverside Fire Laboratory, studied ignition of dry grass by burning cigarettes in a wind tunnel. After hundreds of trials, so few ignitions were achieved that the statistical significance of the findings were questionable (Frank Albini, personal communication, 1993).

If a burning flare reaches the ground or the canopy of a tree or shrub, it may or may not start a fire. The conditions that must be satisfied in order for a fire to start and spread include:

- The source must be very near or in contact with a fuel element.
- The source must have sufficient residual energy to ignite the fuel element.
- Fuel conditions must support the spread of fire.

The first condition can be assessed on the basis of geometric consideration. The probability of a flare landing on the crown layer of a tree or shrub, for example, can be estimated as a function of the fraction of the surface area covered by trees and shrubs. A burning flare alighting in the crown layer of shrub cover may start a fire, but the crown layer must contain a sufficient density of dead foliage with low enough moisture content to support the spread of fire, or no fire will result.

If there is a wind blowing on the heated element, flaming ignition is more difficult to initiate, as the reactive gaseous products of pyrolysis may be swept away before they exist in sufficient concentration to support a flame. But if flaming combustion is initiated, the surface fire will spread much more rapidly under the influence of the wind. When there is an actual flame present, ignition occurs at lower temperatures (approximately 325° C) and is less sensitive to windspeed.

If hot material comes in contact with rotten wood, smoldering combustion can be sustained at temperatures as low as 200° C under most favorable conditions. Fortunately, from the perspective of avoiding the risk of unwanted fire, the fraction of surface area covered by rotten wood is small in even a decadent forest stand (recent studies indicate a maximum near 15 percent in wet sites in northern Idaho).

The probability of ignition given a hot inert item reaching the surface can be assessed based on the moisture content of "fuel" (vegetation and other combustible material on the ground), which in turn can be derived from local meteorological history and current conditions.

5.4.2.2 Assessing the Risk of Unwanted Fire Starts

A system of national scope is in place that numerically gauges the relative danger of wildland fire starts in terms of the susceptibility of various wildland fuels to ignition and fire spread. This system, the National Fire Danger Rating System (NFDRS), is employed by federal, state, and local agencies with land management and fire protection responsibilities. It affords a selection of wildland fuel types that together can be used to characterize most forest and rangeland vegetation cover found in the continental U.S. and Alaska. The NFDRS is used primarily for presuppression planning over large geographic areas. Its indexes give a general assessment of the daily fire potential through the fire season, based on weather observations taken over a network of weather stations forecasts from the National Weather Service. Fire weather observations are archived in a national database that provides a climatology of fire weather that can be used for analyzing and comparing different fire years (Andrews and Bradshaw, no date). The system's indices are sensitive to the phenology of vegetation communities; historical precipitation, temperature, and humidity; and current temperature, humidity, and windspeed.

This system can be accessed by remote computer link to a local office of a federal or state agency (e.g., Forest Service Ranger District, BLM district office, NPS supervisor's office, state natural resource office, etc.). It can also be implemented locally on desktop computer. Using this system, ACC units could devise "no constraint" and "no flare release" guidelines for each training area. Under conditions when a fire would be expected to spread rapidly and/or to burn with high intensity, any risk of ignition may be deemed unacceptable, leading to a "no flare release" constraint. A balance could be struck between the risk of an unwanted fire start, possible consequences of an unwanted fire, and disruption of training operations.

A computer-based fire behavior prediction model, BEHAVE, is currently used by most agencies with wildland fire protection responsibilities. The BEHAVE system is designed to predict the behavior of a specific fire or potential fire (Andrews 1986; Andrews and Chase 1989). It is based on methods described by Rothermal (1983). It is flexible and can be adapted to meet specific needs, utilizing the experience and judgement of fire managers.

In order to use the BEHAVE system, the fuel of an area underlying training airspace must be described in mathematical terms (size, quantity, arrangement, classification as living or dead, and moisture content), and the terrain slope and windspeed must be specified. There exists an assortment of representative fuel descriptions already available (as in NFDRS) that can be used with guidance from consulting local fire control authorities. The range of meteorological conditions that are representative of any site should be available from archived Fire Danger Rating observations taken at the nearest station that takes these data. The observations are routinely archived at the USDA Fort Collins Computer Center in Fort Collins, Colorado and can be retrieved in machine-readable form for a modest fee. There are six regional climate centers that collect daily weather data:

- New England — Ithica, NY, (607) 255-5950
- Southeast — Columbia, SC, (803) 737-0888
- Midwest — Champaign, IL, (217) 244-8226
- South — Baton Rouge, LA, (504) 388-5021
- High Plains — Lincoln, NE, (402) 472-6706
- West — Reno, NV, (702) 677-3139

In addition to models for rate of spread, flame length, and intensity, BEHAVE includes models for spotting distance, area and perimeter growth, scorch height, and tree mortality. One of the models allows the user to estimate fine dead fuel moisture and associated meteorological elements (temperature, relative humidity, wind speed) on a diurnal basis.

The BLM has developed and implemented the Initial Attack Management System (IAMS), a large computer-based system that became operational in 1985 (Andrews and Bradshaw, no date). IAMS covers all BLM lands in the contiguous 11 western states and most of Alaska. IAMS includes remotely sensed lightning occurrence data from the Automatic Lightning Detection System (ALDS), meteorological data from the Remote Automatic Weather Station (RAWS), databases for fuel and topography, and several fire management computer systems. The ALDS consists of a series of electronic sensors that detect the occurrence, location, and polarity of lightning strikes. This information is immediately distributed to fire management offices. The RAWS system provides near real-time weather observations to be used with the lighting data to indicate areas of highest fire occurrence probability. This is used by the BLM to direct aerial flights. The IAMS system distributes data from over 500 RAWS sites. BEHAVE has been incorporated into IAMS, providing an initial indication of potential fire behavior, given a lightning strike and weather, fuel, and terrain information.

5.4.3 Data Gaps and Unresolved Issues

Federal and state land management agencies have developed fire hazard rating and suppression/response procedures for most public and state-owned forest and rangelands. Comparable indices have generally not been developed for DOD ranges (although some may be covered by virtue of being adjacent to public or state lands).

Little information is available on the frequency of fire starts from flares, and very few incidents were reported by ACC units. It is possible that some fires caused by flares were not immediately discovered, and there have been fires of unknown origin that were started by flares.

5.4.4 Conclusions and Recommendations

The assessment of risk of fire from flares use should be classified according to the potential for fire start and potential fire behavior. This type of risk assessment is used by federal land management agencies currently to evaluate activities on lands they manage. For example, firewood cutting activities and camp fires are prohibited during periods of high fire risk.

Because of the type of fire information required (fuel type, weather conditions, and terrain) for fire hazard evaluation, risk assessment must be performed on a site-by-site basis. The procedures for setting up a fire hazard evaluation, however, can be standardized. The fire hazard and behavior prediction models are in public domain software.

As part of this study, a field analysis could be conducted at one or two locations (two locations with different conditions would provide a contrast) where flares are currently used. This would provide an example that could be used for guidance in performing analyses at other locations. A manual on how to perform a fire hazard assessment could be developed based on the case study.

Other recommendations include:

- Establishing a central database and modeling capability, for example at Headquarters ACC, where the BEHAVE model is resident, along with on-line access to weather data. ACC units could obtain output from the BEHAVE model to assist in evaluating site-specific hazards. Assistance would be required from knowledgeable experts to interpret the data, but this could be obtained by the unit by contacting a local fire suppression agency (e.g., federal or state forestry agency).

- ACC units should follow Forest Service, BLM, and state guidelines in determining when it is safe to use flares over their respective lands. Flare use should be curtailed during periods identified as high fire risk.

5.5 AIR QUALITY

5.5.1 Issues Pertaining to Flare Use

Flares are comprised primarily of magnesium which when ignited provides a more intense heat source than an aircraft engine. Air quality impacts could occur from both the flare materials and the explosive charges used to eject and ignite the flares.

Air quality issues with flare use include:

- Compliance with the NAAQS.
- Potential for emission of toxic air pollutants.
- Potential for effects on visibility in PSD Class I areas.

In order to assess compliance with the NAAQS, it is necessary to evaluate whether flares generate or release any criteria air pollutants. The flare combustion products must be assessed to evaluate compliance with the NAAQS for regulated compounds.

The EPA, by a mandate under Title III of the 1990 Clean Air Act Amendments, regulates emissions for 189 listed hazardous air pollutants. Therefore, it is necessary to assess whether any components of flares or the combustion products formed from explosive charges and ignited flares are considered hazardous air pollutants and may cause adverse health effects.

Flares emit a small quantity of visible smoke when ignited, but because of the small quantity and the large area over which they will be deployed, no adverse impacts are anticipated (USAF 1983). However, the potential for visibility impairment from flare usage merits consideration for PSD Class I areas.

5.5.2 Summary of Existing Literature/Information

A literature search was conducted using DIALOG databases centered on "flare" as the major topic. The word flare was paired with other key words such as air pollution, combustion, countermeasure, components, materials, and emission to narrow the scope. The key words were used to search ten DIALOG databases (Aerospace, CA Search, Current Technology, Inspec2, Janes Defense and Aerospace News/Analysis, NTIS, Pollution Abstracts, PTS Newsletter, and PTS Aerospace/Defence Markets and Technology). None of these databases contained documents addressing air emissions associated with flares or the effect of flares on air quality. The DIALOG literature search did not uncover any data, research, or other documentation addressing emissions or air pollution associated with flare usage, emission factors for hazardous air pollutants generated from flare use, or the effect of flare release on air quality.

The material composition for flares is presented in section 5.2. Typically, flares contain a mixture of magnesium with Teflon and Fluorel binder (polytetrafluoroethylene-a) wrapped in aluminum-reinforced tape. Analytical data on the exact weight percentages of the flare components was not available.

In general, the available analytical data addressing combustion products formed from ignited flares is limited. Most of the studies focus on flare burn time in association with release altitudes. One source explains that the flare pellet when ignited burns at a temperature of 2000° F for 3 to 8 seconds depending on flare type (SAIC 1991). Actual burn times are classified but can be characterized as less than 10 seconds. Fall rates have been variously estimated as approximately 500 feet in 5 seconds for the M-206 flare (SAIC 1991) to 200 feet in the same time period for the MJU-7/B (USAF 1989). Only one study provided data on typical compositions of combustion products from MJU-10/B flares. Analytical results of the MJU-10/B flare combustion products identifies the following compounds: magnesium oxide, magnesium chloride, magnesium fluoride, carbon, and trace amounts of carbon monoxide, carbon dioxide, and oxygen difluorine (see Section 5.2.1).

Some test burn analyses have been conducted to obtain information on flare residue. Results from a Moody AFB test burn of six MJU-7/B flares indicate that no residue or ash was produced and only the plastic end cap and felt spacer survived (USAF 1989). Flare residue reportedly consists of a plastic end cap and portion of the plastic piston, slider assembly, and felt spacers. Another evaluation of residue from MJU-7/B flares concluded that the magnesium flare pellet is totally consumed during the burning, plastic pieces weighing 2 ounces will usually be consumed, and a small lead bracket weighing 0.3 ounces may or may not reach the ground. The utilization of lead brackets in flares may be a potential source of toxicity on the ground and merits further investigation. However, the flare debris, mainly plastic and metal (most metal debris is not lead), remains intact and is essentially non-biodegradable. On the ground flare debris would not impact air quality.

Several different types of impulse cartridges are used for flares. Typical flare impulse cartridges contain boron, potassium perchlorate, titanium with potassium dichromate, calcium chromate, and potassium nitrate. Not all of these compounds are contained in each flare impulse charge. The complete material composition and weight percentage for each type of flare impulse cartridge is needed to evaluate air quality impacts since potassium dichromate and calcium chromate lead to the formation of chromium (III) and chromium (IV), which are hazardous air pollutants.

Materials of composition for the impulse cartridge BBU-36/B, which is used in the MJU-10/B, MJU-7/B, and MJU/7A/B type flares, are provided in Table 5.2-3 and include boron, potassium perchlorate, Viton A, potassium nitrate, binder, loose fill, and #2400 smokeless powder. The laboratory analysis of MJU-10 cartridge residue provided by Tracor indicated trace amounts (less than 0.05 grams) of boron oxide, potassium, and chromium oxide. Neither boron oxide nor potassium poses any potential air quality impacts. The only compound which is regulated as an air toxic under CAA is chromium oxide. The presence of chromium oxide in the analysis may be a result of using an older initiator predating the removal of chromium products. The M-206 flare uses a M-796 impulse cartridge. As can be seen on Table 4.2-1, this cartridge still contains calcium chromate (80 mg).

Although chromium is recognized as a carcinogenic material, an emission standard has not yet been established by the EPA. At this time, the American Conference of Governmental Industrial Hygienists (ACGIH) recommends a threshold limit value for chromium (VI) of 0.5 mg/m^3. Based on the potential significance of chromium as a hazardous air pollutant, further investigation of impulse charge residues and combustion products is warranted.

For a preliminary investigation, the annual amount of chromium emitted from usage of the flare impulse charge was evaluated. Based on M-206 flare total annual usage data, 110,464 flares are dispensed over the entire United States by the Air Force. One initiation charge is utilized to eject and ignite each flare. The annual total amount of chromium that is discharged into the atmosphere throughout the United States is 2,945,000 mg or 6.49 pounds.

The 85,326 M-206 flares deployed annually on the Goldwater Range/Sells MOA provide a worst case scenario for evaluation. This annual flare usage would generate 5.014 pounds per year of chromium emissions. For the worst case scenario, all of the chromium was assumed to be hexavalent chromium.

Although these emissions are quite small, due to the high toxicity of hexavalent chromium, additional investigations are required to evaluate potential air quality/health impacts from usage of flares. For instance, in California, facilities with emissions as low as 0.1 lb per year are required to conduct a health risk under California's Assembly Bill 2588. To evaluate the air quality impacts, additional information is required. Both the actual percentage of hexavalent chromium formed during the combustion process and the flare release area and release altitudes are necessary for the evaluation.

The MJU-7/B uses a safety and initiation-electrically fired pyrotechnic squib. To initiate the process, a firing pin strikes the primer assembly firing the ignition charge, a 15 mg charge consisting of basic lead styphnate, lead azide, barium nitrate, antimony trisulfide, and tetracene. The ignition charge fires the output charge composed of a 40 mg mixture of zirconium, molybdenum trioxide, and potassium perchlorate. The output charge then ignites the flare pellet. If these impulse charge material compositions are used, additional data on weight percentages and combustion products will be necessary to evaluate the air quality impacts from this type of flare impulse charge.

The simulator version of the MJU-7/B, the MJU-7(T-1)/B, replaces the magnesium flare pellet with a smoke charge. The smoke charge material consists of 20% powdered sugar, 36% potassium chlorate, 42% yellow dye (Chinoline Yellow-5), and 2% rubber-teflon binder. The sugar and binder components are organic and should oxidize completely to form oxides of carbon, nitrogen, and sulfur. The potassium chlorate provides oxygen for the reaction, decomposing to form potassium chloride.

Other than its name, no information was found concerning the yellow dye. If Chinoline Yellow-5 is a true dye and not a pigment, then it is a complex organic substance, which will decompose to form oxides of mostly carbon and nitrogen. However, if Chinoline Yellow-5 is actually some sort of pigment, it may contain one or more toxic metals. Some of the yellow pigments listed in toxicology texts contains cadmium (CdS), barium and chromium ($BaCrO_4$), lead and chromium ($PbCrO_4+PbSO_4$), mercury (HgO), arsenic (As_2S_3), tin (SnS), strontium and chromium ($SrCrO_4$), or zinc and chromium ($AnCrO_4$). It is likely that a dye would decompose and lose its color immediately upon ignition. On the other hand, an inorganic pigment would be more likely to retain its crystal structure and its yellow color after the explosion.

5.5.3 Data Gaps and Unresolved Issues

No existing information concerning air quality impacts from flare usage is currently available. Information on composition and combustion of flare coatings and impulse charge materials, including the individual weight percentages for each identified composition material and combustion product, is required to conduct a complete air quality analysis. Specific information on flare charge composition and combustion products formed (both compounds and weight percentages) is necessary since it appears that some of the components are considered air toxic pollutants (chromium).

To estimate concentrations for comparison with standards, the flare release area (in square miles) is needed with a breakdown of flare deployment by altitude. If information on the breakdown of flare release by altitude is not available, typical release altitudes may be substituted to estimate flare concentrations. The maximum number of flares deployed per sortie or mission is needed to estimate the one-hour maximum concentrations. The maximum number of flares released during a one-hour period, the release area (in square miles), and the breakdown by altitude for the flare released is needed to evaluate the air quality impacts.

5.5.4 Conclusions and Recommendations

An analysis based on the limited available data on flares did not provide any definitive conclusions regarding air quality impacts from flares. It appears that flare components do not lead to the production of air toxics. However, there is concern that a number of air toxics may be produced during detonation of some flare impulse charges and from some coatings.

Additional testing/data collection is recommended to quantify and qualify the products formed by combustion of the M-796 impulse charge and MJU-7/B ignition charge. Specifically, all the combustion products containing chromium and lead must be identified and their weight percentages determined since chromium and lead compounds are hazardous air pollutants. If flares producing hazardous air pollutants continue to be used, an air toxics risk assessment should be performed. This could be avoided if calcium chromate and any other hazardous air pollutants are eliminated from flares initiators, as has been done with cartridges used for chaff.

5.6 PHYSICAL RESOURCES

5.6.1 Issues Pertaining to Flare Use

Issues pertaining to potential effects of flares on physical resources include:

- Effects of flares on soil and water chemistry.
- Effects of accumulated flare debris on soils and water.
- Impacts on soils and water due to flare-induced fires.
- Effects on water quality related to sedimentation.

5.6.2 Summary of Existing Literature/Information

Most of the existing information on flare types and use was obtained from Air Force correspondence, including EAs and Air Force Form 813. The majority of these documents were requests to employ M-206 and MJU-7/B self-protection flares within certain airspace corridors.

Commonly drawn conclusions are that there would be no debris remaining after ignition and burning and, thus, no environmental impacts would result from the use of flares. However, other correspondence discusses the amount and weight of debris and duds generated from the use of M-206, MJU-7, and MJU-10 flares. Furthermore, data from Nellis Range, where M-206 and MJU-7 flares are utilized, indicate that approximately 2,500 pounds of flare-related debris, excluding duds, accumulated in 1989 and 1,012 pounds in 1990.

Military specifications allow a 5 percent dud rate for flare manufacturing, but based on lot acceptance program criteria, it is estimated that the dud rate averages no more than 1 percent for MJU-7 flares (Morphew 1989). Laboratory-based estimates of failure for other types of flares within the Air Force inventory do not exist. Field estimates of dud frequency and recovery were developed for Nellis and Fallon ranges (SAIC 1991; Morphew 1989). In a three year period at Nellis range, a total of 50 duds were recovered from areas within 1,000 feet of targets and 100 feet of access roads. At Fallon, 20 duds were estimated to accumulate per year. Both domestic and foreign duds and debris were found.

Explosive subassemblies which ignite MJU-7/B flares after ejection from the aircraft contain lead styphnate, lead azide, barium nitrate, antimony trisulfide, and tetracene in the ignition charge (15 mg total) and zirconium, molybdenum trioxide, and potassium perchlorate in the output charge (40 mg total). Chemical data for other types of flares are not available. These explosive by-products, as well as the flare debris, may potentially be considered hazardous waste (see Section 3.1.5).

Most potential impacts discussed in the available literature revolve around the minimum drop altitudes for each type of flare, length of burn time for each flare type, and the associated fire hazards. Some documents address flare debris as a solid waste issue, commonly concluding that the debris would be dropped over such a large area that it would not impact the environment. With the exception of one EA (Taylor 1983), impacts to water resources are not addressed.

5.6.3 Data Gaps and Unresolved Issues

There have been very few laboratory or field studies that address the potential impacts of flare use on earth resources. Data are lacking on all aspects of potential chemical reactions of flares, flare debris, and ignition by-products in all soil types. For example, it is not known whether chemical reactions take place if debris or ignition by-products are deposited in alkaline soils, or whether lead-containing by-products leach out into the soil and ground water. Unresolved issues include whether duds and flare debris would be considered hazardous waste.

There have been no studies conducted that address the potential impacts of flares on water resources. Data gaps and unresolved issues concerning the impacts of flares in these resources include potential chemical reactions of flares and ignition by-products such as boron, potassium perchlorate, potassium dichromate, and calcium chromate in all water quality conditions. It is not known what chemical reactions would take place if a dud were to enter an alkaline water environment.

5.6.4 Conclusions and Recommendations

The majority of documents that address the use of flares contain conclusions of no impact to earth and water resources, although there is no scientifically sound data to support these conclusions. Field and laboratory studies could be conducted to support the conclusions of no impact. A field soil sampling study in areas of heavy flare use (such as target areas), along with laboratory leachability studies, would help develop an understanding of the chemical reactions flare and flare debris might undergo. Field studies in heavy flare use areas could include collection of soil samples at specific depths (e.g., surface, 1/2 foot, 1 foot, and so on) from specific locations on a grid system, and comparison of the chemical analyses of these samples to those of soil samples from a control or background location. Laboratory experiments could examine the effects of chronic long-term exposure of duds and flare debris to different soil conditions. If duds and flare debris are considered hazardous waste, this affects how they are handled, including accumulation and collection times, and may necessitate soil sampling in and around areas that receive heavy flare use.

Virtually no information is available on the effects of flares and flare by-products on water resources. Field or laboratory studies and experiments could be conducted to determine the effects of flares and by-products on water quality. These studies would also help develop an understanding of the potential chemical reactions that could take place if a flare were to enter a water body. It would be important to determine the fate of some of the ignition by-products such as boron or chromates (chromium) which are EPA-listed chemicals under the Safe Drinking Water Regulations (EPA 1992). Studies could examine physical accumulation to determine the effects of long-term build-up or exposure to flares and ignition by-products on water resources and aquatic ecosystems.

5.7 BIOLOGICAL RESOURCES

5.7.1 Issues Pertaining to Flare Use

The main potential impacts and concerns pertaining to the effects of flares on biological resources include:

- Startle effects on birds and other wildlife upon flare ignition.
- Fires due to burning flares reaching the ground or duds igniting on the ground.
- Remnant flare particles reaching the ground and causing physical or chemical changes to biological resources.

5.7.2 Summary of Existing Literature/Information

5.7.2.1 Startle Effects on Birds and Other Wildlife Upon Flare Ignition

Use of flares, particularly at night, could startle wildlife and may temporarily impair vision. Species most likely to be affected by the bright light are nocturnal predators such as owls, bobcats, and mountain lions and nocturnal foragers such as some species of rodents. Effects of individual flares would be local and of short duration. Because flares may be dropped only within special use airspace where disturbances to wildlife would already be frequent, the startle effect of flares would likely be minimal in comparison.

5.7.2.2 Fires Due to Burning Flares Reaching the Ground or Duds Igniting On the Ground

A fire could result if a burning flare reached the ground or if a dud ignited upon contact with the ground. Sometimes dud flares will not ignite upon release from the aircraft. Some types of flares contain a spring-loaded firing mechanism that may be ignited upon impact with the ground or during subsequent handling if recovered. The resultant fire could have adverse effects on the surrounding environment by removing and altering habitat and potentially causing erosion and sedimentation. Fires in arid areas could have long-term ecological impacts.

The significance of the impact from a flare-induced fire depends on the frequency of fires and the extent of damage. Fire probabilities and resulting effects are addressed in more detail in Section 5.4. The resulting effects on biological resources, independent of the cause of the fire, are well documented. Since these impacts are not unique to flares fires, they are not described in detail in this report.

General types of effects from fire are listed in Section 5.4. It should be noted, however, that the significance of these impacts will vary depending on the sensitivity of the environment affected and the species within the area burned. Destruction of sensitive habitats such as wetlands and the habitats of threatened and endangered species, for example, is considered more significant than fires that affect only common resources. The sensitivity of a particular environment and its biological resources should be considered in determining the level of risk of fire that will be taken. Increased restrictions on flare use, including types of flares, locations of use, altitudes, time of year, and weather conditions may need to be imposed in airspace over sensitive habitat areas.

5.7.2.3 Remnant Flare Particles Reaching the Ground and Causing Physical or Chemical Changes to Biological Resources

Flares consist primarily of a magnesium pellet attached to a small plastic and lead bracket. The magnesium is ignited when it is discharged from the aircraft and is totally consumed during the burning. The plastic and other debris may or may not be consumed with the magnesium. Any flare remnants that might reach the ground would be small in number and should present no serious biological concerns as they consist primarily of magnesium, a relatively inert element. Also, since the flares do not drift like chaff, there should be less problem with remnants reaching unauthorized areas (Taylor 1983).

5.7.3 Data Gaps and Unresolved Issues

Most of the data on the effects of flares are based on historical use information from ranges that have been using flares for an extended period of time. Historical data do not provide information on the probability of fires caused by flares or the number of duds that land on the ground. There are no studies specifically addressing startle effects or impacts from chemical effects due to flares on wildlife.

5.7.4 Conclusions and Recommendations

Based on existing evidence, the release of flares seems to have minimal effects on biological resources, except as a result of fires. Burning flares may induce a fear response from wildlife, especially if the flare is released at night. However, these impacts are likely to be short-term and local.

To assess the potential for visual impairment to wildlife, a study could be conducted to measure the light intensity and duration of burning flares from wildlife habitats in or near a range both during the day and at night. A light meter would be used to determine the intensity in the field. If there is any resulting concern based on those findings, laboratory tests could be conducted with various species to determine whether any are temporarily blinded and, if so, for how long.

5.8 LAND USE AND VISUAL RESOURCES

5.8.1 Issues Pertaining to Flare Use

Flare use effects on land use and visual resources can result from three causes: flare debris, dud flares, and fire damage. The temporary effect of a flare illuminating in the sky is considered minor and not an issue. The following is a summary of the issues:

- Debris from flare cartridges creates litter on the ground. This can affect users' attitudes and uses of outdoor recreation areas.
- Dud flares lying on the ground could create a hazard and/or interfere with certain land uses.
- Fires caused by of flares could displace an existing land use.
- Fires caused by flares could effect the visual quality of private and public lands.

5.8.2 Summary of Existing Literature/Information

A literature search of the DIALOG database did not yield any information on flare use in relation to land use or visual resource effects. However, literature on related topics, such as fire and forest management, effects of fire on user landscape preferences, and visual resource assessment is abundant.

5.8.2.1 Land Use

The first step in assessing effects of flare use is to determine if underlying areas are over open water or land. Impacts will also vary depending on underlying land ownership, land use, and specially designated areas and the land use objectives for these areas. In addition to these factors, climate and ecological conditions will influence the effects of flares use, particularly as it relates to the potential for fires.

Determining land ownership underlying flare use areas will provide information about land use objectives. Flares dropped over land controlled by the DOD may leave small quantities of debris, but these will not affect use of the area for military training activity. Fires on military land could potentially affect wildlife and vegetation. In most cases, fire suppression capabilities are available to prevent spread of fires that may threaten human life, and to contain them within military property. Dud flares may present a slight safety risk to ground crews on military lands, but these areas are routinely cleared of unexpended ordnance, including dud flares, to prevent the build up of hazardous explosive and combustible material. The land use objective in military areas is to provide an arena for military activities that may be incompatible with other land uses.

For areas outside DOD-owned or controlled areas additional assessment is required. The sensitivity of particular land use categories to the potential effects from flares is summarized in Table 5.8-1.

Specially Designated Areas

Specially designated lands are sensitive to all adverse effects from flares. These areas, which include Wilderness Areas, Wilderness Study Areas, National Parks, Wild and Scenic Rivers, and some coastal zone and wildlife protection areas, have land use objectives to maintain particular qualities. This is discussed in more detail in Section 4.7.2. These areas are sensitive to effects on wildlife, plants, soil and water, and aesthetics since they are managed to preserve and maintain particular environments. Any external effects that would alter their natural condition would be incompatible. National forests and grasslands and other public lands are generally managed to optimize mixed uses, including forestry, livestock grazing and recreation, and are less sensitive to external intrusions.

The greatest potential adverse impact on land use would be from fires caused by flares. Fires can destroy habitat and wildlife and threaten human safety. The degree of effect depends on the damage caused by the fire, land use objectives, aesthetic value, and the number of people exposed to a hazard. Special use areas are sometimes managed to allow for only natural ecological changes, and not changes induced by man. Fire management is a critical issue in areas with public access and use. It used to be the policy of most federal agencies to put out all fires. Management practices have been shifting, since it has become clear that fire is a natural agent and part of ecological cycles (see Section 5.4). Current management practices tend to let some fires burn and limit intervention to situations that could turn into large scale fires and threaten human life and habitation. A common fire management technique is the "prescribed burn." Using this technique, land managers intentionally create small, manageable fires to limit fuel build up. These fires clear out small dry debris or "forest litter" and thus reduce the potential for a large scale fire. Land managers must integrate the utility of controlled burning with the less predictable effects of natural fires. Reducing the potential source of manmade fires increases their control over external sources of fire. Therefore, controlling potential sources of manmade fires allows for more successful fire management and better utilization of limited resources for coping with fires.

Dud flares and flare debris, depending on quantity, can be incompatible with maintaining special use areas for outdoor recreation, wildlife protection, and naturalness. Flare debris components are small and not particularly noticeable, but they are also relatively durable and do not decompose. In remote outdoor recreation areas, although the chance of running into a dud flare is very low, its contrast to other elements in the landscape will attract attention, potentially increasing the likelihood that the item would be picked up.

Agricultural Lands

Timber areas, croplands, and rangeland are sensitive to effects on animals and plants caused by fires. Fire can be a problem in rural areas where fire suppression capabilities may be less

Table 5.8-1. Sensitivity of Land Use to Flare Impacts

Land Use/Specially Designated Area	Debris Accumulation	Duds	Physical Fire Damage	Aesthetic Fire Damage
Wilderness	H	H	H	H
Wildlife Preservation	M	L	H	M
Coastal Zone	H	H	H	H
Wild and Scenic River	H	H	H	H
Park/Monument	H	H	H	H
Forest	L	M	H	M
Cropland	L	Unknown	H	L
Rangeland	L	L	H	L
Industrial	L	M	M	L
Mining	L	M	M	L
Commercial	L	H	M	L
Recreational	M	H	H	H
Residential	M	H	H	H

H = High M = Medium L = Low

available. Fire response time can be greater, equipment and water less available to put out large scale fires, and the fire can result in consumption of economic resources.

Dud flares may also have the potential to be ensnared in equipment, particularly in agricultural areas. The impacts of such an event are not known. Foresters and farm operators typically cover large areas of land fairly thoroughly, and are likely to come across dud flares on their land. Their risk is higher than that of recreation users who typically travel along established trails, thereby reducing the exposure area.

Industrial and Commercial Land Uses

Industrial and commercial land uses would not be sensitive to aesthetic or ecological effects. Damage caused by fires would be the primary impact on industrial and commercial uses. Industrial complexes in remote areas, such as mining operations and power plants, could be affected. The probability of this kind of fire occurring is remote, however, as structures and developed areas are generally avoided by training aircraft. Dud flares may pose a hazard where human activity is concentrated in industrial and commercial areas. However, since these areas account for a small amount of the land area in remote areas and they are generally avoided in training, the probability of impact is very low.

Recreation

Outdoor recreational activity would be sensitive to changes in wildlife, plants, soil, water, and aesthetics resulting from fires caused by flares. Changes that resulted in loss of wildlife and areas of scenic value could affect recreational activities such as hunting, camping, hiking, sight seeing and observing wildlife. Studies have shown that campers' photo-based judgements about scenic beauty are related to their willingness to pay for recreation opportunities. Studies have also shown that forest fire damage affects perceived scenic beauty in an area (Vaux et al 1984). Therefore, fire effects may result in changes in visitation and user selection of recreation areas.

Dud flares and other litter could be a curiosity if found by recreationists. Campfires would provide an external heat source, hot enough to ignite a dud flare. Dud flares may be carried home and transported into other environments for extended periods of time, increasing the likelihood of the dud eventually being ignited.

Residential Areas

Flare debris is unlikely to cause changes in residential use. However, dud flares and fire damage could pose safety hazards and potential property damage. Residential pockets in remote areas are particularly susceptible to hazards of forest fires. Dud flares would pose a similar hazard to residential uses as it does to outdoor recreationists.

5.8.2.2 Visual Resources

Factors to consider in assessing visual resource effects include the quality of the visual environment, sensitivity of the area to changes in that environment, and the degree to which flare use is evident in the environment. When they ignite, flares creates a visual effect for the 10 second duration of the burn. This would be noticeable, especially at night, but the impact would be short-term and temporary. Flares use may be visually evident through accumulation of debris, but primarily, through damage from fires. Fires caused by flares would have the same kind of visual effects as other uncontrolled fires.

Public lands are often classified for their visual quality by land custodians. The systems used by the Forest Service and the BLM are outlined in Section 4.7.2.2. Class 1 Visual Resource areas and Preservation areas are the most valued visual resources, and include all Wilderness Areas, Wild and Scenic Rivers, National Parks and Monuments, and some wildlife areas. These areas are managed to prevent the intrusion of incompatible activities. The purpose of the visual quality rating systems is to guide land managers in choosing appropriate land management techniques. Areas with high visual resource value can accommodate less visually noticeable intrusions. For example, when using prescribed burns to control build up of forest undergrowth, different patterns and strategies for burning can be selected depending on the kinds of visual impacts that an area has the capacity to absorb. Placement and landscaping of firebreaks is carefully designed to meet visual quality objectives (Benson et al 1985; Bacon and Dell 1985). Also, different methods and levels of timber harvesting can be prescribed to result in the least disturbance to sensitive visual resources.

Most of the nation's most highly valued visual resources have been acquired over the last century, in order to protect them and to make them available for the public benefit. However, some state-controlled and private lands with high visual quality and value may also exist, and some public lands have not yet been classified. In general, landscapes in mountainous areas and areas with variations in relief, great vistas, and variations in land forms will tend to have high visual appeal.

Different environments are more sensitive than others to change. Environments which have great emotional significance to large numbers of people due to their beauty or symbolic meaning will be sensitive to visual alteration. Areas that are used or visited by large numbers of people will also be more sensitive to change.

The degree to which flare damage is evident in the environment will depend on several factors. Duration of the effect on the environment is a consideration in assessing visual impact. In the case of fire, damage can be fairly long lasting. Viewing duration is another factor to consider. Some changes will be less noticeable when viewed from moving vehicles than areas viewed primarily by pedestrians/equestrians.

Studies have been conducted to measure people's sensitivity to landscape changes and preferences, particularly in relation to landscape management activities. One study presented photographs of natural landscapes with and without structures and management actions to assess if the actions were detectable, identifiable, and whether liked or disliked (Magill 1990). These studies provide information to managers about visual thresholds, or the capacity of landscapes to absorb change, and about the kinds of changes that attract the least attention. Studies have also shown that people prefer natural landscape features, forest stands being the most frequently favored feature (Magill 1992). Although roads are the most noticed manmade feature, clear cut areas, and objects perceived as clear cuts, elicited the greatest level of dislike (Magill 1992). Damage from forest fires may be perceived as clear cuts or have the same visual impact in some viewing situations, and thus have a high potential for visual dissatisfaction. There is evidence to suggest that education can alter public attitudes and judgments of management activities when they are perceived to have long term goals to enhance and protect natural environments (McCool et al 1986).

Many studies have been done to rate people's preferences for landscapes that are both affected and unaffected by fire. In order to get an accurate evaluation, the condition of any given landscape over time needs to be considered (Vaux et al 1984). Studies have shown that when comparing photographs of different places before and after fire, at certain time intervals, and comparing them to similar ecological settings without fire over time, people will usually ascribe higher scenic value to the unburned area initially. However, after a few years, a burned environment may have fresh new growth and maintain open, park-like features under a high-crown forest, resulting in high visual appeal. An unburned area may have more dense undergrowth which is inhospitable and less attractive to forest users. It cannot be said that forest fires unequivocally result in visual resource degradation over time.

Forest fire, forest harvesting, insect disease, and fire prevention techniques can all present visual alterations to the landscape. The degree of contrast that results and the degradation of visual quality depend on a number of factors. These include the size of the altered area, the distance from the viewer, the complexity of the surrounding landscape (and relative dominance of the alteration), color, texture and pattern of the landscape, and duration of effect. For example, a large forest fire will alter large areas of vegetation which will create different patterns and forms in a vista. These may not detract from the visual setting if other features dominate the view and only minor changes in color or hue are evident to a distant viewer. However, the impacts of fire in the foreground may be much more obvious and detrimental. At the same time, foreground areas will tend to recover more quickly as lush new green growth succeeds within a few years of the fire. Areas that have low visitation will be relatively less affected. Small fires affecting only low undergrowth may not be perceived from distant viewing locations and only impact foreground viewing perspectives.

Other evidence of flares that can enter the visual environment are debris, such as cream-colored plastic ejector mechanism parts and small felt pads. These parts are very small and would only be noticeable in the close-up environment. Visual impacts of this debris would be similar to other small litter items in the environment. Dud flares would be visually similar to chaff casing debris (discussed in Section 4.7.2.2), and would only be noticeable on the ground in the foreground.

5.8.3 Data Gaps and Unresolved Issues

Impacts on land use from flare fires will depend on the extent of fire damage. Fire risk varies with climatological and ecological conditions. However, the anticipated size of flare-induced fires in various environments is unknown. The potential for flare-induced fires to jeopardize large areas is addressed in Section 5.4.

Effects of flare components as debris in the environment on equipment, particularly farm equipment, is not known.

Sensitivity of users to forest fires in specific settings and how this would affect their use patterns and willingness to pay would be site specific. Alternative opportunities, distance, and accessibility would need to be assessed for specific flare use training areas.

The degree to which flare fires would add a burden on small rural fire protection services and consume or damage resource dependent land uses (such as rangeland, forest) is unknown.

The degree to which flare debris and dud flares are visible and noticeable in natural settings where flare training is performed needs to be determined to assess the level of visual impact.

5.8.4 Conclusions and Recommendations

5.8.4.1 Land Use

The effect of flare debris as litter on user attitudes about scenic beauty and subsequent land use choices would probably be insignificant due to the small size of debris components and lack of contrast with other elements in the foreground environment. However, field observations should be conducted to confirm low noticeability. Additional research on the sensitivity of public to litter and affects of litter on public behavior is recommended. Effects of fire damage on land use is dependent on the probability of a flare-caused fire.

All specially designated areas have low tolerance for changes brought on by non-ecological conditions, including litter, and would be least suitable as flare training areas. Depending on the risk of flare fire, using flares over these areas could be incompatible with land uses that concentrate human activity, including parks, monuments, recreational facilities, and residential areas. Flare fires can have serious effects on crop and rangeland uses, particularly in dry areas. Information about specific rural fire suppression capabilities for areas underlying or in the vicinity of flare training areas is needed to assess their adequacy to cope with flare fires that may occur.

Dud flares pose a safety hazard in areas where people congregate or where human activity covers large areas of land. Impacts to land uses would depend on probability of exposure and resultant safety risk. On a site-specific basis where flares are proposed for use in areas with residential development or concentrations of people, the density of dud flares should be estimated and considered when assessing compatibility with underlying land uses.

5.8.4.2 Visual Resources

Effects of fires caused by flares on visual resources would vary depending on the visual sensitivity of the area, the ability of the landscape to absorb visual changes, and the numbers, attitudes, and expectations of viewers. Field studies are needed to determine if there is any visual evidence of flare fires in heavily used areas such as military ranges. However, these areas tend not to have high visual quality and to have been disturbed by military training activity, and they would not be representative of areas underlying MOAs and MTRs. If the effects of flares are evident in heavily used range areas (including visual effects of debris), additional visual surveys should be conducted in more sensitive natural settings.

Flare debris would be perceived as litter. Noticeability would probably be low due to the small size, lack of contrast, and low density of the material. The accumulation of flare debris and dud flares is likely to be insignificant in most cases due to wide dispersion and infrequent viewing. However, contrasting debris in the foreground environment would not be compatible in special-use areas with high visual resource value. Any litter in areas of high (Class 1) visual quality is undesirable, and flare training in overlying airspace would be incompatible with visual resource management goals. Field studies similar to those proposed to assess effects of chaff debris should also be conducted to evaluate evidence of flare debris and duds in natural settings.

5.9 CULTURAL RESOURCES

5.9.1 Issues Pertaining to Flare Use

Cultural resources include any prehistoric or historic district, site, or building, structure, or object considered important to a culture, subculture, or community for scientific, traditional, religious or any other reason. The cultural resources discussed in this section include prehistoric and historic archaeological resources, architectural resources, and traditional Native American resources.

Only significant cultural resources warrant consideration with regard to adverse impacts resulting from a proposed action. To be considered significant, archaeological or architectural resources must meet one or more of the criteria (as defined in 36 CFR 60.4) for inclusion on the National Register of Historic Places. There are no legally established criteria for assessing the importance of a traditional Native American resources, although guidance is currently under development. These criteria must be established primarily through consultation with Native Americans according to the requirements of the American Indian Religious Freedom Act and the Native American Graves Protection and Repatriation Act.

Key Federal laws and regulations that govern the management and protection of cultural resources include the National Historic Preservation Act of 1966, the National Environmental Policy Act of 1969, the Archaeological and Historic Preservation Act of 1974, the American Indian Religious Freedom Act (AIRFA) of 1978, the Archaeological Resources Protection Act (ARPA) of 1979, Executive Order 11593, and the Native American Graves Protection and Repatriation Act (NAGPRA) of 1990.

Cultural resources may potentially be affected by flare-related fires, fire suppression and rehabilitation activities, smoke, and the deposition of debris and duds. Issues include:

- Soil erosion, leading to exposed archeological sites or increased deposition on sites.
- Alteration of lithics by high-intensity fires.
- Distortion or alteration of dating.
- Destruction or alteration of historic structures.
- Destruction of vegetation, habitat, and animal populations important to Native Americans.
- Smoke damage to rock art.
- Smoke damage to historic architecture.
- Smoke damage on Native American sites used for religious activities.
- Litter affecting the aesthetics of sites used for Native American religious activities.
- Disturbance or destruction of archaeological or Native American sites from fire suppression, clean-up, or rehabilitation activities, including effects from heavy equipment, landscape alteration, and potential effects from retardants.

5.9.2 Summary of Existing Literature/Information

Fire could potentially affect cultural resources by promoting soil erosion from the loss of surface vegetation. This could result in the exposure of archaeological sites or in excessive soil deposition, covering sites and moving artifacts. The results of Carbon 14 and Obsidian Hydration dating techniques could potentially be altered by the introduction of carbon into sites and by altering the structure of lithic materials. The complete or partial destruction of historic architecture is a possibility with any fire, if any structures are present. Fire could destroy many Native American resources, including indigenous vegetation, which may lead to the growth of "exotic" species. If traditional gathering of plant foods or materials are important, fires could permanently eliminate habitat and plant population. Also, the reduction of natural habitats could result in a decline and/or a change of animal species or in their displacement. The loss of wildlife could seriously affect attempts by Native Americans to sustain traditional lifeways.

Cultural resources could be damaged by activities undertaken to suppress fires and rehabilitate burned areas, such as cutting firebreaks or mechanical reseeding. Unless care is taken in the creation of fire breaks and in replanting activities, the potential to impact cultural resources is high. Archaeological sites and Native American traditional use areas could be severely impacted by the use of mechanized suppression equipment. Conversely, if conducted with care, fire rehabilitation activities could broaden the archaeological record by revealing previously hidden sites.

Smoke from fires could impact cultural resources by affecting the context and setting of historic buildings and Native American traditional use areas. Smoke may effect archaeological sites, particularly rock art, and may cause damage to historic architecture.

Surviving debris from discharged flares may include metal initiator mechanisms, primer pins, and whole duds. It is unlikely that the deposition of these materials would affect archaeological sites, architecture, or Native American traditional use areas beyond aesthetics. However, ordnance clean-up crews could cause a potential impact through inadvertent damage with vehicles or through collection of artifacts.

Currently, there is no information available specifically on the effects of flares on cultural resources. There is very little direct literature which examines the effects of fires on cultural resources. One study concerning fire and cultural resources examined a number of variables affecting archaeological site formation processes in wildfire areas (Rogers 1988). The study devised a fire value classification system (low, medium, or high intensity) based on the type and amount of vegetation burned. It determined that the impact of low intensity fires on prehistoric sites is minimal, and the impact of medium or high intensity burns is high due to alteration of the physical characteristics of the soil and loss of surface vegetation, which promotes artifact movement. It also reported that fire can confuse the archaeological record by causing thermal fractures and cracks in non-cultural materials.

Existing literature and information on the effects of fire on traditional cultural resources, including vegetation and wildlife, is quite extensive and can be found in a number of studies. The impacts include destruction of native vegetation; introduction of opportunistic exotic species; a reduction of natural habitats, leading to a reduction and/or change of animal species; and death/displacement of wildlife (Helvey, et. al. 1985; Little 1985; Wright 1972).

The effects of fire suppression on archaeological sites and historic buildings was examined in a USDA Forest Service General Technical Report (PSW-109 1989). The report concluded that fire suppression policies and activities have resulted in a buildup of fuel, leading to fewer but more intense fires with a greater capacity for altering lithics. It also reports that another major effect of suppression activities is the disturbance and/or destruction of sites by fire personnel and rehabilitation crews. There is no information available on the effect of fire retardant on cultural resources.

Most federal land management agencies (BLM, Forest Service) have stated policies that address the protection of cultural resources during and after fires. These polices consider cultural resources in pre-suppression planning, normal fire rehabilitation plan development, post-suppression damage assessment, and emergency fire rehabilitation. Such activities are guided by Section 106 (36 CFR 800) of the Historic Preservation Act of 1966.

5.9.3 Data Gaps and Unresolved Issues

The main gap in the data is the inability to predict flare-related fire probability. Such a capability could potentially mitigate the effects of flare use and the resulting fires. This is addressed in more detail in Section 5.4.

5.9.4 Conclusions and Recommendations

The primary cause of impacts to cultural resources from the use of flares is fire and accompanying suppression and rehabilitation activities. To reduce the impact on cultural resources should a fire occur, the following recommendations should be considered during fire suppression and rehabilitation activities:

- Fire suppression and rehabilitation policies should consider the protection of cultural resources.

- Mechanized fire suppression equipment should not be used in areas known to contain archaeological sites or other cultural resources.

- Locations of archaeological sites in/under training areas where flares are used should be identified through consultation with State Historic Preservation Officers and considered in determining what level of risk to take in particular areas.

- Consultation should be conducted with Native American tribes to determine the location of archaeological sites and important topographical features in areas where flares are used (AIRFA 1978; NAGPRA 1990).

- Consultations with local Native American tribes should address effects of suppression and rehabilitation activities (AIRFA 1978; NAGPRA 1990). Consultation should also occur for clean-up of duds if they are deposited in areas of important Native American resources.

- Policies should be developed, based on Forest Service and BLM procedures, to minimize inadvertent damage to cultural resources during fire-fighting activities. Developing such policies in advance will be more effective than expecting fire-fighting crews to incorporate these considerations in the field.

Additional research is needed to fully understand the effects of fire and related activities on cultural resources. These issues are common to fires regardless of cause and not unique to flares, however, and are therefore outside the scope of this study.

6.0 OVERALL CONCLUSIONS AND FUTURE ACTIVITIES

6.1 CONCLUSIONS FROM PHASE 1 RESEARCH

In general, existing data on the environmental effects of chaff and flares are limited and inconclusive. Some conclusions can be drawn from knowledge about the constituent materials and components of these countermeasures (e.g., toxicity data) and how they behave in the environment, or about the ability of environmental resources to assimilate intrusions from chaff and flares.

In drawing conclusions about the potential for impacts, two considerations are important: (1) the probability of an effect occurring, and (2) the severity of the effect itself. These considerations apply to assessing both safety risks and environmental impacts. If the analysis indicates that a potential event is extremely unlikely, such as a person or animal consuming enough chaff to experience toxic effects, this may be adequate to draw a conclusion of no significant impact, even if the effect of an individual event might be significant if it did occur.

The conclusions of this Technical Report consider both probability of occurrence and severity of impact in determining whether specific issues warrant further research, mitigation, or changes in either the materials used or operational procedures employed during training activities. Regulatory requirements have also been taken into consideration and in some cases may increase the level of concern even if the probability and/or severity of impact are low.

Based on these considerations, each issue pertaining to potential impacts of chaff and flares use on a specific resource has been assigned a relative level of concern, as either "negligible," "low," "moderate," or "high." Following are criteria for assigning each level.

- Negligible (or None) — this level of concern denotes an issue with some level of impact that has either so remote a probability of occurring that it is virtually impossible (and there is no known incidence of it having occurred), or the impact has been found to be clearly insignificant.

- Low — this level of concern denotes that the issue is not expected to have a significant potential for adverse impact, but available evidence is not completely conclusive. Additional research may be considered, but its priority would be low.

- Moderate — this level of concern indicates that the possibility of significant impact cannot be dismissed based on available data. The evidence is not adequate to determine conclusively whether or not there is a potential for significant impact. Research to resolve issues in this category would receive relatively high priority.

- High — this level of concern is reserved for issues about which there is sufficient evidence of potential adverse impact that management action is warranted.

The study examines the potential for both acute and long-term impacts in various resource areas. Examples of issues related to acute effects include toxicity (to both humans and animals), compliance with short-term air quality standards, safety risks, and startle effects on wildlife. Long-term issues include chemical effects of accumulation on soil and water, long-term exposure of animals to chaff and flare by-products, and visual effects from the accumulation of litter.

6.1.1 Effects of Chaff Use

The analysis of chaff materials indicates that there are no identifiable health risks and few, manageable safety risks. The materials comprising the chaff itself are relatively nontoxic, particularly in the quantities involved. Therefore, no significant impacts from toxicity, either on humans or on animals, are expected. Some concern may remain over potential hazardous air pollutants released by pyrotechnic devices that eject the chaff from aircraft. Potential for other impacts is generally related to the amount of chaff and debris that may accumulate under training areas over time. Low-use areas are not likely to receive enough of a concentration to generate physical or other effects. The following paragraphs indicate levels of concern relative to specific resource issues, based on the data available to date.

<u>Negligible or No Concern</u>

- Toxic effects on humans from chaff particles.
- Safety risks, except radar interference and powerline contact.
- Impairment of visibility in PSD Class I areas.
- Startle effects among animals from chaff release.
- Inhalation of chaff fibers by animals.
- Irritation of skin or feet of wildlife, except possibly newborn birds and small mammals if chaff has been incorporated in nesting material.
- Increased uptake of aluminum in plants.
- Effects on land use, except in primitive and pristine areas and, possibly, wildlife preserves.
- Chemical effects from chaff accumulation on cultural resources.

Low Concern

- Safety risks from chaff coming in contact with powerlines.
- Impacts from chaff accumulation on soil chemistry.
- Toxic effects on wildlife from ingestion.
- Adverse effects from chaff fibers accumulation on visual resources.
- Aesthetics effects of the accumulation of chaff debris on sensitive cultural resource sites.

Moderate Concern

- Potential for chaff to fragment into respirable particulates regulated under the Clean Air Act.
- Potential for emission of hazardous air pollutants regulated under the Clean Air Act when ejecting pyrotechnic chaff from aircraft.
- Behavior of chaff under anaerobic conditions such as swamps.
- Effects of chaff used as nesting material on newborn birds and small mammals.
- Effects of chaff ingestion on surface-feeding waterfowl, such as some ducks.
- Effects of chaff ingestion on small herbivores.
- Effects of the accumulation of chaff debris (end caps, packages, etc.) in recreation areas, parks, and wildlife preserves.
- Visibility of chaff and associated debris in other than Class 1 or Preservation Visual Resource Management Areas.

High Concern

- Potential for chaff to interfere with air traffic control and other radar. This concern can be mitigated by converting to chaff packages that have the problematic fiber lengths removed.
- Accumulation of chaff debris in pristine natural areas such as Wilderness Areas, Wild and Scenic Rivers, PSD Class I areas, and Class 1 and Preservation Visual Resource Management Areas. Most of these areas are currently avoided in chaff training.

6.1.2 Effects of Flare Use

Flares differ from chaff in that they are designed to be completely consumed (except for incidental debris) in the air. Therefore, issues of accumulation of material are less pressing. The primary issues arising from use of flares are related to acute effects, particularly fire (although the secondary effects of fire can be long-term). This and other safety concerns may result in serious impacts; however, the probabilities associated with these hazards are low. The probabilities associated with hazards from dud flares, for example, are less than 5 percent of the number of flares used, since the specifications for the manufacture of flares require that they be at least 95 percent reliable. Since some of the initiator cartridges used with flares are known to contain hazardous air pollutants (chromium and lead), there appears to be a need for a more detailed evaluation of health risks under the Clean Air Act. In addition, there is a concern that dud flares qualify as hazardous waste.

Almost all of the potential significant impacts identified for flares, on any environmental resource, were related to fire. Because there are so many variables with very low or unknown probabilities involved in calculating the probability of a single flare starting a fire, that then results in significant impacts, such calculations may not produce statistically valid results. No fire incidents from flares were found in DOD mishap databases (although they are known to have occurred), so existing data are not adequate to estimate probabilities. It is possible more useful data may be obtained through non-DOD land management agencies, such as BLM, U.S. Forest Service, and state forestry departments. Computer models are available for predicting the risk of a fire, should one start, spreading and causing a significant impact, but this analysis can only be performed on a site-specific basis.

Levels of concern relative to specific resource issues are identified below.

<u>Negligible or No Concern</u>

- Toxicological effects on humans from ingestion.
- Safety risks, except for fire and risks involving dud flares.
- Impacts on biological resources, except potential visual impairment in animals and impacts from fire.

<u>Low Concern</u>

- Probability of a falling dud flare hitting a person (although the effect could be catastrophic).
- Chemical effects of dud flares on soil and water.
- Burning flares causing visual impairment in animals.

- Accumulation of litter from flare use.
- Dud flares becoming entangled in agricultural or industrial machinery.

Moderate Concern

- Potential for injuries to Air Force personnel from hung duds.
- Potential for civilian injuries from picking up duds.
- Potential for duds collected in airtight containers to produce explosive hydrogen gas.
- Emission of hazardous air pollutants by initiators.
- Potential for dyes used in simulator flares to contain hazardous air pollutants.

High Concern

- Potential for fires under certain circumstances to spread and result in significant impacts on soil, water, biological resources, land use, visual resources, and cultural resources.

6.2 RECOMMENDED FUTURE ACTIVITIES

This section presents suggestions for changes in the composition of chaff and flares or in their use during training operations to avoid or mitigate issues of high concern, or identified as having the potential for regulatory conflict or environmental impact. These suggestions are followed by recommendations for additional research to address unresolved issues of concern.

6.2.1 Suggested Mitigation Measures

Some specific suggestions for mitigating potential adverse effects on environmental resources from the use of chaff and/or flares are included in the resource analyses in Sections 4.0 and 5.0. This section focuses on a few overall suggestions that appear feasible and reasonable and have the potential for avoiding a possible conflict or precluding the need for extensive additional analysis. The proposed mitigation measures fall into three categories: (1) changes in the composition of chaff and flare units, (2) restrictions on use under certain conditions, and (3) other management actions.

Changes in Materials

Certain materials historically used in chaff and flare initiators contain hazardous air pollutants. Some changes have already been made to reduce the generation of toxic substances, although these changes may not be reflected in some of the older inventory still available for use. Specific suggestions are:

- Remove any existing inventory of chaff containing lead (if any still exists).

- Confine future chaff procurements to models in which the fiber lengths that interfere with air traffic control radar have been removed. Confine use of older inventory still containing those fibers to special use airspace areas where there is no risk of the chaff cloud drifting outside of the area.

- Change initiator cartridges in future flare procurements to eliminate use of chromium products. This change has already been made to the BBU-35/B cartridge used with chaff. Making a similar change in the cartridges used with flares would eliminate the need to conduct potentially extensive health risk assessments for compliance with the Clean Air Act, under which chromium is listed as a hazardous air pollutant.

Operational Restrictions

Restrictions on use of chaff and flares are already included in Air Force and ACC regulations. The purpose of the following suggestions is to confirm or clarify continued application of certain restrictions to avoid potential conflicts identified in this study. Specific suggestions are:

- Avoid releasing chaff or flares over Wilderness Areas, Wild and Scenic Rivers, National Parks and Monuments, PSD Class I areas, and areas identified as Class 1 Visual Resource Management (BLM) or Preservation (U.S. Forest Service).

- Avoid dropping flares over residential areas, high-use recreation areas, and any areas where people tend to concentrate.

- Adopt use restrictions or altitude restrictions for use of flares over or near BLM, U.S. Forest Service, and state forestry department lands during periods of high fire hazard. Coordinate with applicable land management agencies to identify and avoid fire hazards.

Consideration could also be given to avoiding, to the extent practicable, releasing chaff over major waterfowl congregation areas and wildlife protection areas with significant water resources, although the potential for adverse impacts has not yet been established.

Other Management Actions

Consideration should be given to establishing a capability to perform computer fire modeling, perhaps at Headquarters ACC, using the BEHAVE computer program. This capability could be used in a similar manner as the NOISEMAP contour modeling capability to support environmental analyses of proposed flare use in areas outside DOD lands (as well as some DOD-owned lands with fire concerns).

6.2.2 Recommendations for Additional Research

Recommendations for additional research include a combination of field study, laboratory analysis, modeling analysis, and agency consultations. A field study would support several resource areas by determining whether there are any observable effects from historic use of chaff and flares. It is recommended that two locations with relatively high historic chaff and flare use be analyzed, providing different environments and ecological conditions. If no observable effects are noted at high-use locations, it can be postulated that no effects would be observed at lower use locations. On the other hand, if observable effects are found at the high-use locations, additional field analysis may be warranted at lower use sites.

In selecting candidate locations for consideration, the highest use chaff areas do not necessarily correspond with the highest use flares areas, but, based on information compiled in Section 2.0 and other sources, the best overall candidates are the Nellis Range Complex in Nevada, the Utah Test and Training Range, Barry Goldwater Range in Arizona, and the Eglin AFB complex. The Utah Test and Training Range provides limited ecological diversity under the authorized chaff and flares areas, so the Nellis Complex may offer the most useful environmental conditions for an arid climate. To provide a contrast, a range in the eastern U.S. is recommended as the second location, with Eglin AFB apparently offering the highest use. The Eglin area also provides over-water (W-460) and shoreline environments that could be examined.

The field study would support a number of resource analyses. For chaff, the primary objective would be to determine whether there is any visible accumulation of chaff or other debris over the area in general and in specific areas where it might tend to collect, such as the shorelines of water bodies, the windward side of slopes, etc. If possible, a density of chaff and chaff litter would be estimated. For flares, observations would focus on the noticeability of debris and effects from past fires. Each field site would be visited by a team comprising a geologist or hydrologist, a biologist, and a land use specialist.

As part of the field program, soil and water samples would be collected in accumulation areas and at a control site for each location. These samples would be returned for laboratory analysis to determine whether there are any chemical differences between the affected areas and the control areas that could be attributed to chaff or flares use. During the field visit, measurements would also be taken of the illumination levels created by flares to ascertain potential effects on animal vision. If chaff accumulations are observed, in-field examinations would be made of bird and small mammal nests to see if any chaff has been used for nesting material. Depending on the findings of the field study, additional studies may be warranted of various animal species, as described in Sections 4.6 and 5.7.

The field study locations would also be modeled for fire hazard, using the methodology described in Section 5.4. This would provide sample case studies that could be used as guidance for future site-specific analyses.

Controlled laboratory studies are recommended in a number of areas. One is a medium-term (e.g., one year) study of the chemical behavior of chaff in various samples of water (fresh and saline; different pH levels; different temperatures; anaerobic conditions). A similar test could be conducted for soils, although the potential for adverse effects appears so remote as to make this a low priority. Laboratory analysis of the behavior of chaff in stomach acid could also be conducted.

One of the unresolved issues is whether chaff fibers break up into particle sizes with an equivalent diameter of 10 microns or less. Further research will be conducted to find out whether any analysis has previously been performed (e.g., by manufacturers). If not, modeling or laboratory analysis may be required to estimate the percent of particles of respirable size formed during ejection to complete the air quality analysis.

The air quality analysis will include dispersion modeling of chaff fibers. There has been much discussion about the dispersion and subsequent deposition of chaff, but as Section 4.4 indicates, it has limited applicability, and its usefulness must be put in perspective. Dispersion modeling is expected to have little value in evaluating long-term effects from chaff use, due to the random nature of chaff training operations. It may be helpful in estimating how far chaff is likely to drift from release areas, to identify the geographic extent of potential impacts. Its main utility, however, is in evaluating acute effects and addressing short-term issues, such as how long a chaff cloud may remain airborne (where it can interfere with radar). Dispersion modeling can also be used to calculate maximum 1-hour and 8-hour concentrations of air pollutants for comparison with air quality standards.

In addition to air quality modeling, further analysis is required of some safety issues. The probability estimates provided in Sections 4.3 and 5.3 are based on available mishap data. These data are limited, and some postulated safety hazards have no record of occurrence over the past ten years. Therefore, the probability estimates in the Safety sections need to be verified/validated. Almost all of the postulated hazards were estimated to have low enough probabilities that the associated risks fell into "Acceptable" ranges. Hazards that involve higher risks, in particular fire risks from flares use and risks from duds, need further analysis. Although expected to be very low, because the effects of a person being hit by a falling dud flare are potentially catastrophic, probabilities should be more precisely calculated. The same is true for risks of injury from mishandling dud flares.

Finally, the contacts made in compiling this report were primarily confined to DOD sources. Other agencies may have information of value in analyzing safety and environmental effects from chaff and flares. It is recommended, therefore, that contacts be made with a variety of federal and state agencies in areas where chaff and flares are currently used, in order to identify their concerns as well as collect applicable data they may have. Agencies that should be contacted include FAA, DOI, BLM, U.S. Forest Service, U.S. Fish and Wildlife Service, and state forestry, natural resources, and land management departments. The appropriate level (office within each organization) will be identified to ensure maximum benefit from these contacts. Introductory correspondence will probably be needed to facilitate cooperation at the appropriate level of each organization.

The efforts described above are expected to resolve most of the issues that may still be a concern. It is possible that some findings will lead to additional research. In combination with the data already available, the additional efforts will provide a basis for characterizing both acute and long-term effects from chaff and flares use. However, although no longer term research needs have been identified to date, it should be noted that the most extensive research included in these recommendations does not extend beyond a year's time.

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Jim Dederick	M.S., Water Quality Hydrology, Colorado State University; B.S., Watershed Sciences, Colorado State University; 14 years experience in hydrology analysis	Physical Resources
Pete Figura	B.A., Environmental Science, Claremont McKenna College; 3 years experience in environmental impact assessment	Biological Resources
Susan Goodan	M. Architecture, University of New Mexico; B.A., Ethics/Archaeology, University of Cape Town; 5 years experience in environmental assessment	Land Use/Visual
Adam Hasen	M.B.A., Management, San Diego State University; M.S., Chemical Engineering, University of Connecticut; B.S., Chemical Engineering, University of Arizona; more than 10 years experience in air quality and air pollution	Air Quality
Gita Mondal	M.P.H, Environmental Health, San Diego State University; B.S. Biology, University of California, Irvine; 1-1/2 years experience in risk assessment, regulatory compliance, and health and safety guidance	Toxicology/Health Effects
Kevin Peter	M.A., Anthropology, Washington State University; B.A., Anthropology, Pomona College; 14 year experience in archaeology and cultural resource management	Cultural Resources

Karen Pope	B.A.; Environmental Science, Claremont McKenna College; 3 years experience in environmental impact assessment	Biological Resources
Andrea Randall	B.S., Chemical Engineering, Colorado State University; more than 4 years experience in air quality and air pollution control equipment	Air Quality
Robert Rea	M.S., Aeronautical Engineering, Air Force Institute of Technology; B.S., Civil Engineering, Texas A&M; CE Civil Engineer, Columbia University; MBA, Business Administration, Registered Professional Engineer, University of Phoenix; 34 years of experience	Composition and Materials
Grant Reynolds	AB, Bates College; J.D. Columbia University; 32 years of experience	Regulations and Policies
Jil Sevy	B.A., Anthropology, Boise State University, 1989, 4 years of experience	
Angela Sewall	M.S., Geoscience, University of Nevada; B.A., Earth Sciences, St. Cloud State University; 7 years experience	Physical Resources
Robert W. Smith	B.A., Psychology, 1960, Willamette University, 26 years experience	Airspace Management/ Training Operations
Eric Tambini	B.A. Geological Sciences, University of California, Santa Barbara; Hazardous Waste Management Certificate; 8 years of experience	Physical Resources
Bob Thompson	M.A. Human Resources Management, Peperdine University; B.S. Mathematics, Heidelberg College; 25 years experience of air traffic control and airspace management	Airspace Management/Training and Operations
Rosie Thompson	Ph.D., Marine Biology, University of California, B.A., Zoology, University of Missouri; 21 years experience in environmental impact assessment	Biological Resources

Rob Thomson	M.S., Ecology, University of California; B.S. Zoology, University of California; 17 years experience in environmental impact assessment	Safety
Michael R. Zanotti	M.P.A., Administrative Management and Organization, Golden Gate University; B.A., Behavioral Sciences, University of Maine; 11 years experience in safety and emergency management	Safety

APPENDIX A

Chaff and Flares Document Database

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
271	25 FTTS/WFF, Ellsworth AFB	Message to Aircrews	US Air Force, Air Combat Command	2/23/93	Las Vegas, NV	message	2
31	347 TFW/DO, Moody AFB	MJU-7/B Flare Environmental Assessment	USAF	1/23/89	Santa Barbara, CA, Albuquerque, NM	EA, AF Form 813	15
49	9 AD, Shaw AFB	Flare Employment	USAF-TAC	6/1/90	Albuquerque, NM	memo	1
125	Aeronautical Systems Division	Critical Iten Specification for Dual Chaff, Counterfmeasures, RR-180/AC	ASD and Tracor, W-P AFB		Albuquerque, NM	specification	4
126	Aeronautical Systems Division	Critical Item Fabrication Specification for Chaff, Countermeasures, RR-141 D/AL	USAF - ASD, Tracor, W-P AFB	2/27/85	Albuquerque, NM	specification	9
118	Air Logistics Center	Diagrams and notes for Flare Types MJU-7, M-206, MJU-10/B and Residue Diagrams	Ogden Air Logistics Center, Hill AFB		Albuquerque, NM	Diagrams and photocopies	7
177	Alderson, M.R.; Rattan, N.S.; Bidstrup, L.	Health of Workmen in the Chromate-production industry in Britain	British Journal of Industrial Medicine	1/1/81	San Diego, CA	Article	8
115	Alfonsi, Capt, 57 OSS/OSOT, Nellis	Bullet Background Paper on IR Counter Measure Flare Type	USAF - 57 OSS/OSOT	9/23/92	Albuquerque, NM	info report	1
195	Anderson, E.L. and Carcinogenic Assessment Group (CAG)	Quantitative Approaches in Use to Assess Cancer Risk	Risk Analysis	1/1/83	San Diego, CA	Article	19
44	Anderson, Eric, MAJ, SAC	B-52 Use of Chaff & Flares for Mt. Home AFB CW	USAF-SAC	12/2/91	Albuquerque, NM	memo	1
54	Andrews, Patricia; Bradshaw, Larry	Use of Meteorological Information for Fire Management in the U.S.	Intermountain Research Station, Forest Service	n.d.	Albuquerque, NM	report	8
45	Apple, Kent	Point Paper on Chaff & Flare Use in Mt. Home Airspace	Mt Home AFB, DOW	11/26/91	Albuquerque, NM	point paper	3
37	Armament Development and Test Center, Eglin AFB	Environmental Assessment, ALE-38 Multi-Frequency Chaff Evaluation	Electronic Programs Branch Armament Development and Test	1973 (?)	Santa Barbara, CA, Albuquerque, NM	EA	13

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
151	Armament Division Hill AFB ALC	Specification for flare assembly - MJU-7A/B	Hill AFB ALC	3/27/91	Albuquerque, NM	spec.	20
56	Armour, Charles D.; Bunting, Stephen C.; Neuenschwander, Leon F.	Fire Intensity Effects on the Understory in Ponderosa Pine Forests	Journal of Range Management, vol. 37, Number 1	1/1/84	Boise, ID		5
57	Arno, Stephen F.; Davis, Dan H.	Fire History of Western Redcedar/Hemlock Forests in Northern Idaho, Proceedings of the Fires History	U.S. Dept. of Agriculture, Forest Service	1/1/80	Boise, ID	General Technical Report RM-	5
37	armament Development and Test Center, Eglin AFB	Environmental Assessment, ALE-38 Multi-Frequency Chaff Evaluatin	Electronics Programs Branch, Armament Development and Test Center, Eglin AFB	1/1/73	Albuquerque, NM	EA	13
38	Arnold, L. H.	Environment Assessment for Dispensing Chaff in Conjunction with the Young Warrior OT&E	Strategic Air Command, Eglin AFB, Florida	1/1/74	Santa Barbara, CA	EA	8
18	Arnold, Lloyd H., Capt. USAF	Environment Assessment for Dispensing Chaff in Conjunction with the Young Warrior OT&E	SAC Project Office - Eglin AFB	7/18/74	Albuquerque, NM	EA	8
211	Axelsson, G.R.; Rylander R.; Schmidt A.	Mortality and incidence of tumors among ferr-chromium workers	British Journal of Industrial Medicine	1/1/80	San Diego, CA	Article	8
196	Azar, A.; Trochimowicz, H.J.; Maxfield, M.E.	Review of Lead Studies in Animals Carride out at Haskell Laboratory - Two year feeding study and response to	Int'l Symposium on Environmental Health Aspects of Lead	1/1/73	San Diego, CA	Article	10
162	Bacon, Warren; Dell, John	National forest Landscape Management, Vol. 2, Chap. 6, FIRE	USDA, Forest Service	4/1/85	Albuquerque, NM	handbook	90
178	Baetjer, A.M.	Pulmonary Carcinoma in Chromate Workers; Incidence on basis of hospital records	Arch. Ind. Hyg. Occup. Med.	01/01/50(b)	San Diego, CA	Article	12

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
212	Baetjer, A.M.	Pulmonary carcinoma in chromate workers. I. A review of the literature and report of cases	Arch. Ind. Hyg. Occup. Med.	1/1/50 (a)	San Diego, CA	Article	17
42	Baker, D. A.	Case of the Aluminum Foil (A Study in Public Relations)	Historical Division, Office of Information Services, Headquarters Air Materiel Command	3/1/56	Santa Barbara, CA	Report	6
16	Baker, Doris A.	Case of the Aluminum Foil	Historical Division-Office of Information Services HQ Air Materiel Command	3/1/56	Albuquerque, NM	report	5
19	Barrett, B.B., and MacKay, R.R	The Ingestion of Fiberglass Chaff by Cattle	Animal Diseases Research Institute, Canada Dept. of	11/1/71	Albuquerque, NM, Santa Barbara, CA	report	5
58	Baughman, Robert G (compiler)	An Annotated Bibliography of Wind Velocity Literature Related to Forest	Dept. of Agriculture, Forest Service,	1/1/81	Boise, ID	General Technical	28
153	Benson, Robert; McCool, Stephen; Schlieter, Joyce	Attaining Visual Quality Objectives in Timber Harvest Areas - Landscape Architects' Evaluation	USDA, Forest Service	8/1/85	Albuquerque, NM	research paper	9
179	Bidstrup, P.L.	Carcinoma of the Lung in Chromate Workers	British Journal of Medicine	1/1/51	San Diego, CA	Article	4
180	Bidstrup, P.L.; Case, R.A. M.	Carcinoma of the Lung in Workmen in the bichromates-	British Journal of Industrial Medicine	1/1/56	San Diego, CA	Article	5
181	Bittersohl, G.	Epidemiological Research of Cancer Cases in the Chemical Industry	Arch. Geschwulstforschl	1/1/71	San Diego, CA	Article	12
52	Blake, Gary, 832 AD/DOA	MJU-7T-1/B "Smokey Devil" Flare Simulator Employment	USAF - TAC	2/25/91	Albuquerque, NM	AF Form 813	8
187	Block, R.B.; Schiff, S.C.	Effects of Aluminized Fiberglass on Representative Chesapeake Bay Marine Organisms	Systems Consultants, Inc.	1/1/77	Santan Barbara, CA	Report	

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
213	Bonatti, S.; Meini, M.; Abbondandolo, A.	Genetic effects of potassium dichromate in Schizosaccharomyces pombe	Mutation Research	1/1/76	San Diego, CA	Article	4
182	Brinton, H.P.; Frasier, E.S.; Koven, A.L.	Morbidity and Mortality Experience Among Chromate Workers	Public Health Rep.	1/1/52	San Diego, CA	Article	13
60	Brown, James K	Downed Dead Woody Fuel and Biomass in the Northern Rocky Mountains	Dept. of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station	1/1/81	Boise, ID	General Technical Report INT-117	48
59	Brown, James K.	Physical Fuel Properties of Ponderosa Pine forest	Dept. of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station	1/1/70	Boise, ID	Research Paper INT-74	16
62	Brown, James K.; DeByle, Nobert V.	Effects of Prescribed Fire on Biomass and Plant Succession in Western Aspen	Dept. of Agriculture, Forest Service, Intermountain Research Station	1/1/89	Boise, ID	Research Paper INT-412	16
63	Brown, James K.; Marsden, Michael A.; Ryan, Kevin C.; Reinhardt, Elizabeth D.	Predicting Duff and Woody Fuel Consumed by Prescribed Fire in the Northern Rocky Mountains	Dept. of Agriculture, Forest Service, Intermountain Forest and Range	1/1/85	Boise, ID	Research Paper INT-337	23
61	Brown, James K.; Simmerman, Dennis G.	Appraising Fuels and Flammability in Western Aspen: A Prescribed Fire Guide	Dept. of Agriculture, Forest Service, Intermountain Research Station	1/1/86	Boise, ID	General Technical Report INT-205	48
159	Brown, Thomas; Daniel, T.; Richards, M.; King, D.	Recreation Participation and the Validity of Photo-based Preference Judgments	Journal of Leisure Research	1/1/88	Albuquerque, NM	article	20
188	Browning, E.	Toxicity of Industrial Metals	Butterworths, London	1/1/69	Santa Barbara, CA	Book	

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
164	Bureau of Land Management (BLM)	Visual Resource Inventory	US DOI, BLM	1/1/1986 (a)	Albuquerque, NM	handbook, 8410-1	portions
165	Bureau of Land Management (BLM)	Visual Resource Contrast Rating	US DOI, BLM	1/1/1986 (b)	Albuquerque, NM	handbook, 8431-1	portions
166	Bureau of Land Management (BLM)	Environmental Assessment for Visual Resources	US DOI, BLM	nd	Albuquerque, NM	manual - 8430	25
270	Bureau of Land Management (BLM)	Guidance for the Protection of Cultural Resources Specific to Fire	US Bureau of Land Management	1/1/93	Boise, ID	Manual Supplement	
175	Casarett, L.J.; Doull, J.	Toxicology: The Basic Science of Poisons	Macmillan Publishing Co.	1/1/86	San Diego, CA	Book	
197	Casto, B.C.; Meyers J.; Dipaolo, J.A.	Enhancement of Viral Transformation for evalution of the carcinogenic or mutagenic	Cancer Research	1/1/79	San Diego, CA	Article	6
113	Chapman, Randall, LT Col, Commander, Nellis	Staff Summary Paper - Flare Use in MOAs	USAF 57 OSS/OSOT	23/09/92	Albuquerque, NM	AF Form 1768	1
64	Cleary, Brian D.; Greaves, Robert D.; Hermann, Richard K.	Regenerating Oregon's Forests: A Guide for the Regeneration Forester	Oregon State University Extension Service	1/1/78	Boise, ID	Book	287
111	Clements, Edward, COL, Vice Commander, Nellis	Flare Use in MOAs	USAF - WTC/CV	27/08/1992	Albuquerque, NM	memo	1
120	Collins, Thomas, E., HQ 3246 Test Wing, Eglin AFB	Flare Fragment Velocity Data	USAF - AFSC	2/25/92	Albuquerque, NM	letter/charts	8
65	Cooper, Charles	The Ecology of Fire			Boise, ID		10

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
66	Cooper, Charles F.	Changes in Vegetation, Structure, and Growth of Southwestern Pine Forests Since White Settlement	Ecological Monographs, vol. 30, No. 2	1/1/60	Boise, ID		35
198	Cooper, W.C.	Mortality among employees of lead battery plants and lead producing plants, 1947-1980	Scand. J. Work Environment Health	1/1/85	San Diego, CA	Article	15
200	Cooper, W.C.; Gaffey, W.R.	Mortality of lead workers	Proceedings of the Conference on Standards of Occupational Lead Exposure	1/1/75	San Diego, CA	Article	8
67	Crane, M.F.; Fischer, William C.	Fire Ecology of the Forest Habitat Types of Central Idaho	Dept. of Agriculture, Forest Service, Intermountain Research Station	1/1/86	Boise, ID	General Technicla Report INT-218	86
96	Crane, M.F.; Fischer, William C.	Fire ecology of the forest habitat types of central Idaho	Dept. of Agriculture, Forest Service, Intermountain Research Station	1/1/86	Boise, ID	General Technical Report INT-218	86
155	Daniel, Terry; Brown, T.; King, D.; Richards, M.; Stewart, W.	Perceived Scenic Beauty and Contingent Valuation of Forest Campgrounds	Forest Service	1/1/89	Albuquerque, NM	magazine article, Forest Science 35(1)	15
214	Davies, J.M.	Lung Cancer mortality in workers making chrome pigments	Lancet	1/1/78	San Diego, CA	Article	1
215	Davies, J.M.	Lung cancer mortality of workers in chromate pigment manufacture: An epidemiological survey	Journal of Oil Chemistry Association	1/1/79	San Diego, CA	Article	7

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
68	Davis, Kathlenn M.; Clayton, Bruce D.; Fischer, William C.	Fire Ecology of Lolo National Forest Habitat Types	Dept. of Agriculture, Forest Service, Intermountain Forest and Range	1/1/80	Boise, ID	General Technical Report INT-79	77
46	Day, Lawrence, Brig Gen, Asst Deputy Chief of Staff Ops	Self-Protection Flare Training	USAF-TAC	5/1/88	Albuquerque, NM	report	4
137	Defense Documentation Center	Pyrotechnics	Department of Defense	11/1/72	Campus Point, SD	abstract	1
148	DIALOG Information Services	Bibliography of Chaff/Flares Articles & Reports	SAIC	1/18/93	Oak Ridge, TN	bibliography	74
201	Ding-wall Fordyce, I.; Lane, RE	A Follow-up study of lead workers	British Journal of Industrial Medicine	1/1/63	San Diego, CA	Article	3
202	Dipaolo, J.A.; Nelson, R.L.; Casto, B.C.	In vitro neoplastic trans-formation of Syrian hamster	British Journal of Cancer	1/1/78	San Diego, CA	Article	4
118	Donley, James, Lt. Col.	Use of Flares in MOAs	USAF - HQ Fighter Weapon Center (TAC)	4/21/92	Albuquerque, NM	memo	1
121	Donley, James. Lt Col, TFWC, Director of Safety	Memo; AF Forrm 813; Background Paper on IRCM Flare and Flare Simulator Hazards	USAF - Fighter Weapons Center (TAC)	1/22/92	Albuquerque, NM	paper/memo	8
147	DROLS	DROLS Bibliography on Chaff and Flares	HQ AFCESA/TIC	1/8/93	Oak Ridge, TN	bibliography	67
145	DTIC	Technical Report Summaries	99th TTW/TIC	2/19/93	Oak Ridge, TN	bibliography	44

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
158	Dunn, Michael	Landscape with Photographs: Testing the Preference Approach to Landscape Evaluation	Journal of Environmental Management	1/1/76	Albuquerque, NM	article	11
183	Enterline, P.E.	Respiratory Cancer Among Chromate Workers	Journal of Occupational Medicine	1/1/74	San Diego, CA	Article	4
193	EPA, Office of Water	Drinking Water Regulations and Health Advisories	US EPA	1/1/92	Colorado Springs, CO		
9	Federal Aviation Administration	Joint ASM/ATO Procedures for Coordinating ECM Mission Requests	HQ-FAA	5/19/87	Albuquerque, NM	order 7601.11	8
70	Ferguson, Dennis E.; Stage, Albert R.; Boyd, Raymond J.	Predicting Regeneration in the Grand Fir-Cedar-Hemlock Ecosystem of the Northern Rocky Mountains	US Dept. of Agriculture, Forest Service, Intermountain Forest and Range Experiment	1/1/86	Boise, ID		41
71	Fiedler, Carl E.; McCaughey, Ward W.; Schmidt, Wyman C.	Natural Regeneration in Intermountain Spruce-Fir Forests--A Gradual Process	Dept. of Agriculture, Forest Service, Intermountain Research Station	1/1/85	Boise, ID	Research Paper INT-343	12
157	Fischer, David	Willingness To Pay as a Behavior Criterion for Environmental Decision-Making	Journal of Environmental Management	1/1/75	Albuquerque, NM	article	12
73	Fischer, W. C.	Plant and Wildlife Species List	Fire Effects Information System	1/1/87	Boise, ID		4
74	Fischer, W. C.; Clayton, Bruce C.	Fire Ecology of Montana Forest Habitat Types East of the Continental Divide	Dept. of Agriculture, Forest Service, Intermountain Forest and Range	1/1/83	Boise, ID	General Technical Report INT-141	83

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
72	Fischer, William C.; Bradley, Anne F.	Fire Ecology of Western Montana Forest Habitat Types	Dept. of Agriculture, Forest Service, Intermountain Research Station	1/1/87	Boise, ID	General Technical Report INT-223	95
102	Forest Service	Fire management notes, vol. 45, no. 3	Dept. of Agriculture, Forest Service	1/1/84	Boise, ID	notes	31
103	Forest Service	When the mountain roared: stories of the 1910 fire	Dept. of Agriculture, Forest Service		Boise, ID		38
160	Forster, Bruce	Valueing Outdoor Recreational Activity: A Methodological Survey	Journal of Leisure Research	1/1/89	Albuquerque, NM	article	20
34	Fort Valley State College, Division of Agriculture	Magnesium in the Environment: Soils, Crops, Animals and Man	Div. of Agriculture, Fort Valley State College, Fort Valley, GA	1/1/72	Santa Barbara, CA Public Library	Symposium	8
216	Fradlin A.; Janoff, A.; Lane, B.P.; Kuschner M.	In vitro transformation of BHK21 cells grown in the presence of	Cancer Research	1/1/75	San Diego, CA	Article	6
217	Frentzel-Beyme, R.	Lung Cancer mortality of workers employed in chromate pigment factories. A multicentric European epidemiological study	Journal of Cancer Research	1/1/83	San Diego, CA	Article	6
218	Furst, A.; Schlauder M.; Sasmore D.P.	Tumorigenic activity of lead chromate	Cancer Research	1/1/76	San Diego, CA	Article	5
75	Geier-Hayes, Kathleen	Vegetation response to helicopter logging and broadcast burning in Douglas-fir habitat types at Silver Creek, central Idaho	Dept. of Agriculture, Forest Service, Intermountain Research Station	1/1/89	Boise, ID	Research Paper INT-405	24

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
189	Gladwin, D.N.; Asherin,D.A.; Manci, K.M.	Effects of Aircraft Noise and Sonic Booms on Fish and Wildlife: Results of A Survey of USFWS	USFWS, National Ecology Reserach Center	1/1/87	Santa Barbara, CA	Report	24
203	Granjean, P.; Wulf, H.C.; Niebuhr E.	Sister chromatid exchange in response to variations in occupational lead exposure	Environmental Research	1/1/83	San Diego, CA	Article	6
117	Griffith, Thomas, Maj. Gen.	Aircraft Self-Protection Flare Use in MOAs	USAF	6/18/92	Albuquerque, NM	memo	1
76	Gruell, George E.; Brown, James K.; Bushey, Charles L.	Prescribed fire opportunities in grasslands invaded by Douglas-fir: state-of-the-art guidelines	Dept. of Agriculture, Intermountain Research Station	1/1/86	Boise, ID	General Technical Report INT-198	19
15	Hadley, James A., COL	Consumption of Aluminum Foil by Animals	USAF, Strategic Air Command	10/1/64	Albuquerque, NM	letter	2
77	Haig, Irvine T.; Davis, Kenneth P.; Weidman, Robert H	Natural regeneration in the western white pine type	Dept. of Agriculture, Forest Service, Northern Rocky Mountain Forest and	1/1/41	Boise, ID	Technical Bulletin No. 767	99
78	Harrington, M.G.	The effects of spring, summer, and fall burning on gambel oak in a	Forest Science, vol. 31, No.1	1/1/85	Boise, ID		8
79	Harrington, Michael G.	Predicting reduction of natural fuels by prescribed burning under Ponderosa pine in Southeastern Arizona	Dept. of Agriculture, Forest Service, Rocky Mountain Forest and	1/1/87	Boise, ID	Research Note RM-472	4
53	Hartford, Roberta	Decisions and Fire Prediction in Fuel and Fire Management, Vo.2, No.2	Blue Mts. Natural Resources Institute	Spring1992	Albuquerque, NM	Newsletter	2
55	Hartford, Roberta; Frandsen, William	When It's Hot, It's Hot...Or Maybe It's Not! (Surface Flaming May Not	US Dept of Agriculture, Forest		Albuquerque, NM	report	6
150	Haydon, Douglas S. Lt Col.	AFR 127-4, Investigating and Reporting US Air Force Mishaps	HQ AFISC/SEPX	1/3/90	Oak Ridge, TN	USAF Reg.	176
184	Hayes, R.B.;Lilienfeld, A.M.; Snell, L.M.	Mortality in Chromium Chemical Production Workers: A	Int. Journal of Epidemiology	1/1/79	San Diego, CA	Article	10
173	Hazardous Substance Data Bank (HSDB)	Magnesium Oxide; Magnesium Chloride; Ferric Oxide; Stearic Acid		1/1/93	San Diego, CA	Report	
80	Helvey, J.D.; Tiedemann, A. R.; Anderson, T.D.	Plant nutrient losses by soil erosion and mass movement after wildfire	Journal of Soil and Water Conservation,	1/1/85	Boise, ID		
127	Hill AFB	Purchase Description for Chaff Countermeasures, RR-170 A/AC	Engineering Div, Hill AFB?	7/22/80	Albuquerque, NM	specification	29

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
140	Hill, Novella S.	AF-Reg 50-46	USAF	6/8/87	Boise, ID	reg	78
185	Hill, W.J.; Ferguson, W.S.	Statistical Analysis of Epidemiological data from a	Journal of Occupational	1/1/79	San Diego, CA	Article	4
124	HQ ACC/DO, Langley AFB	Aircraft Self Protection Flare Use in MOAs	USAF - HQ ACC	7/20/92	Albuquerque, NM	memo	1
51	HQ TAC	ECM Clearance Request for Chaff Drops	USAF-TAC	4/1/90	Albuquerque, NM	info sheet	2
48	HQ TAC/DOO	Self Protection Flare Training	USAF-TAC	3/1/89	Albuquerque, NM	memo	2
10	HQ Wright Air Development Center	Lead Content of Chaff	HQ Wright Air Development Center	5/1/56	Albuquerque, NM	Memo	1
13	HQ-TAC/DOO	Use of Self-Protection Chaff and Flares on USAF Air-to-Ground Gunnery Ranges	HQ TAC/DOO	3/9/84	Albuquerque, NM	AF Form 813	4
219	Hueper, W.C.	Environmental carcinogenesis and cancers	Cancer Research	1/1/61	San Diego, CA	Article	16
220	Hueper, W.C.; Payne, W.W.	Experimental cancers in rats produced by chromium compounds and their significance to industry and public health	Industrial Hyg.	1/1/59	San Diego, CA	Article	7
221	Hueper, W.C.; Payne, W.W.	Experimental studies in metal carcinogenesis: Chromium, nickel, iron, and arsenic	Arch. Environ. Health	1/1/62	San Diego, CA	Article	18

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
265	IMR Powder Company	Data sheet	IMR Powder Company, Plattsburgh NY	7/1/78	Albuquerque, NM	Report	portions
186	Integrated Risk Information System (IRIS)	Chromium; Lead	US EPA	1/1/90	San Diego, CA	Reports	
222	Ivankovic, S.; Preussmann R	Absence of toxic and carcinogenic effects after administration of high doses of chromic oxide pigment in	Food Cosmet. Toxicol.	1/1/75	San Diego, CA	Article	5
82	Kane, Robert E.; Arno, Stephen F.; Brown, James K.	FIRESUM-an ecological process model for fire succession in western conifer	Dept. of Agriculture, Forest Service,	1/1/89	Boise, ID	General Technical	76
168	Kaplan, S.; Kaplan, R.; Wendt, J.S.	Rated Preference and Complexity for Natural and Urban Visual Material	Psychonomic Society	1/1/72	Albuquerque, NM	article in Perception and Psychophysic	3
204	Kasprzak K.S.; Hoover, K.L.; Poirier, L.A.	Effects of dietary clacium acetate on lead subacetate carcinogenicity in kidneys of male Sprague-Dawley rats	Carcinogenesis	1/1/85	San Diego, CA	Article	4
81	Keane, Robert E.; Arno, Stephen F.; Brown, James K.	FIRESUM-an ecological process model for fire succession in western conifer forests.	Dept. of Agriculture, Forest Service, Intermountain Research Station	1/1/89	Boise, ID	General Technical Report INT-266	76
83	Kie, John G.	Deer habitat use after prescribed burning in northern California	Dept. of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment	1/1/84	Boise, ID	Research Note PSW-369	3
84	Kilgore, Bruce M.	The ecological role of fire in Sierran conifer forests: its application to national park management	Quarterly Research 3	1/1/73	Boise, ID	article	17
85	Kilgore, Bruce M.; Curtis, George A.	Guide to understory burning in ponderosa pine-larch-fir forests in the Intermountain West	Dept. of Agriculture, Forest Service, Intermountain Research Station	1/1/87	Boise, ID	General Technical Report INT-233	39

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
17	Kitzes, George, Dr.	Toxicity of Chaff to Livestock	? Medical Laboratory	1/1/52	Albuquerque, NM	report	2
205	Koller, L.D.; Kerkvliet N.I., Exon, J.H.	Neoplasia induced in male rats fed lead acetate, ethyl urea and sodium nitrate	Toxicological Pathology	1/1/86	San Diego, CA	Article	8
223	Korallus, U; Lange, H.; Ness, E.; Wustefuld, E.; Zwingers, T.	Relationships between precautionary measures and bronchial carcinoma mortality in the chromate-producing industry	Arbeitsmedizin, Socialmedizin, Preventiv-medizin	1/1/82	San Diego, CA	Article	9
225	Langard, S.; Anderson, A.; Glyseth, B.	Incidence of cancer among ferrochromium and ferrosilicon workers	British J. of Ind. Med.	1/1/80	San Diego, CA	Article	7
224	Langard, S.; Norseth, T.	A cohort study of bronchial carcinomas in workers producing chromate pigments	British Journal of Ind. Med.	1/1/75	San Diego, CA	Article	4
226	Laskin, S.M.; Kuschner, M.; Drew, R.T.	Studies in pulmonary carcinogenesis	US Atomic Energy Commission Symposium Series and National Cancer Institute	1/1/70	San Diego, CA	Article	30
227	Levis, A.G.; Buttignol, M.; Bianchi,V.; Sponza, G.	Effects of potassium dichromate on nucleic acid and protein syntheses and on prescursor	Cancer Research	1/1/78	San Diego, CA	Article	7
228	Levy, L.S.; Martin, P.A.	The effects of a range of chromium-containing materials on rat lung (Unpublished)	Dry Color Manufacturers Association	1/1/83	San Diego, CA	Article	
192	Lindsay, Willard L.	Chemical Equilibria in Soils		1/1/79	Colorado Springs, CO		
86	Little, S.N.; Klock, G.O.	The influence of residue removal and prescribed fire on distributions of forest nutrients	Dept. of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment	1/1/85	Boise, ID	Research Paper PNW-338	12
229	Loeb, L.A.; Sirover, M.A., Agarwal S.S.	Infiedlity of DNA synthesis as related to mutagenesis and carcinogenesis	Adv. Exp. Biol.	1/1/77	San Diego, CA	Article	13

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
230	Lofroth, G.	The mutagenicity of haxavalent chromium is decreased by microsomal metabolism	Naturvissenschaften	1/1/78	San Diego, CA	Article	2
87	Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W. (technical	Prceddings--symposium and workshop on wilderness fire	Dept. of Agriculture, Forest Service, Intermountain Forest	1/1/85	Boise, ID	General Technical Report INT-	434
146	Lt. Col. Jerry R. Perkins	Explosive and Flight Mishap Database Statistics	HQ AFSA/SEFD	2/18/93	Oak Ridge, TN & HQ ACC/CEVA, Langley AFB, VA	computer printout	7
152	Lucas, Robert C.	Us Patterns and Visitor Characteristics, Altitudes and Preferences in Nine Wilderness and Other Roadless Areas	USDA, Forest Service	7/1/80	Albuquerque, NM	research paper	90
114	Macfarlane, William, Col, Commander, Nellis	Staff Summary Sheet - Flare Use in Nellis MOAs	USAF - 57 OSS/OSOT	11/12/92	Albuquerque, NM	AF Form 1768	1
231	Machle, W.; Gregorius, F.	Cancer of the respiratory system in the Untied States Chromate-producing industry	Public Health Rep.	1/1/48	San Diego, CA	Article	14
232	MacKenzie, R.D.; Byerrum, R.U.; Decker, C.F.; Hoppert, C.A.; Langham, R.F.	Chronic toxicity studies. II. Hexavalent and trivalent chromium administered in	Am. Med. Assoc. Arch. Ind. Health	1/1/58	San Diego, CA	Article	3
171	Magill, Arthur	Assessing Public Concern for Landscape Quality: A Potential Model to Identify Visual Thresholds	USDA, Forest Service	11/1/90	Albuquerque, NM	research paper	48
172	Magill, Arthur	Managed and Natural Landscapes: What Do People Like?	USDA, Forest Service	7/1/92	Albuquerque, NM	research paper	28
88	Malanson, G. P.; Butler, D. R.	Ordinations of species and fuel arrays and their use in fire management	Forest Ecology and Management	1/1/85	Boise ID	article	6
233	Maltoni, C.	Occupational carcinogenesis	Excerpta Med. Int. Congr. Ser.	1/1/74	San Diego, CA	Article	8
234	Maltoni, C.	Predictive value of carcinogenesis bioassays	Ann. NY Acad. Sci.	1/1/76	San Diego, CA	Article	13
190	Manci, K.M.; Gladwin, D.N.; Villella, R.; Cavendish, M.G.	Effects of Aircraft Noise and Sonic Booms on Domestic Animals and Wildlife: A Literature Synthesis	USFWS, National Ecology Research Center	1/1/88	Santa Barbara, CA	Report	

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [illegible]

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
235	Mancuso, T.F.	Consideration of Chromium as an Industrial Carcinogen	Int. Conf. on Heavy Metals in the Environ.	1/1/75	San Diego, CA	Article	14
236	Mancuso, T.F.; Hueper W.C.	Occupational cancer and other health hazards in a chromate plant: A medical appraisal. I. Lung cancers in chromate workers	Ind. Med. Surg.	1/1/51	San Diego, CA	Article	6
119	Martin, Terry, Lt. Col.	Staff Summary Sheet - MJU-7 Flares	USAF - 57 OSS/OSOT	7/16/92	Albuquerque, NM	AF Form 1768	1
112	Mather, Richard, Col., Vice Commander, Nellis AFB	MJU-7 Flares	USAF - HQ 57 FW/CV	10/6/92	Albuquerque, NM	memo	1
89	McCool, Stephen F.; Stankey, George H.	Visitor attitudes toward wilderness fire management policy 1971-1984	Dept. of Agriculture, Forest Service,	1/1/86	Boise, ID	Research Paper INT-	7
154	McCool, Stephen; Stankey, George	Visitor Attitudes Toward Wilderness Fire Management Policy - 1971-84	USDA, Forest Service	1/1/86	Albuquerque, NM	research paper	9
163	McGuire, John	National Forest Landscape Management, Vol 1, Chap 1, The isual Management System	USDA, Forest Service	4/1/74	Albuquerque, NM	handbook	48
90	Mees, Romain M.	Simulating initial attack with two fire containment models	Dept. of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment STation	1/1/85	Boise, ID	Research Note PSW-378	7
91	Mills, Thomas J.	Integrating fire management analysis into land management planning	Dept. of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment	1/1/83	Boise, ID	General Technical Report PSW-74	8
122	Morphew, Gary, Lt Col, TFWC, Director of Safety	ALA-17B IRCM Flare Trajectory Analysis	USAF - HQ TFWC/SE	5/30/91	Albuquerque, NM	letter	2

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
110	Morphew, Gary, Lt Col, TFWC, Director of Safety et al	IRCM Flare Use in TFCW and MOAs; and misc. memos and AF Form 813 for Chaff and Flare use in MOAs	USAF - TFWC	9/20/89	Albuquerque, NM	Misc. memos, AF Form 813, and info letters	10
123	Morphew, Gary, Lt. Col, TFWC, Director of Safety	IRCM Flare Information	USAF - HQ TFWC/SE	3/8/89	Albuquerque, NM	letter/photo	5
156	Muth, Robert; Clark, Roger	Public Participation Wilderness and Backcountry Litter Control: A Review of Research and Management Experience	USDA, Forest Service	1/1/78	Albuquerque, NM	Technical report	12
237	Nakamuro, K; Yoshikawa, K.; Sayato, Y.; Kurata, H.	Comparative studies of chromosomal aberration and mutagenicity of trivalent and hexavalent chromium	Mutation Research	1/1/78	San Diego, CA	Article	7
239	National Institute for Occupational Safety and Health (NIOSH)	Criteria for a recommended standard occupa;tional exposure to chromium (VI)	US Department of Health, Education, and Welfare	1/1/75	San Diego, CA	Report	
206	Nelson D.J.; Kiremidjian-Schumacher L.; Stotzky, G.	Effects of cadmium, lead, and zinc on macrophage-mediate cytotoxicity toward tumor cells	Environmental Research	1/1/82	San Diego, CA	Article	10
92	Nelson, Ralph M. Jr	Flame characteristics for fires in southern fuels.	Dept. of Agriculture, Forest Service, Southeast Forest Experimental Station	1/1/80	Boise, ID	Research Paper SE-205	14
238	Newbold, R.F.; Amos, J.; Connell, J.R.	The cytotoxic, mutagenic, and clastrogenic effects of	Mutation Research	1/1/79	San Deigo, CA	Article	9
176	Office of Health and Environmental Assessment, Environmental Criteria and	Health Effects Assessment for Lead	US EPA	1/1/84	San Diego, CA	Report	

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
209	Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office	Air Quality Criteria Document for Lead, Volumes III, IV	US EPA	1/1/86	San Diego, CA	Report	
210	OHEA/ECAO	Preliminary review of the carcinogenic potential of lead associated with oral exposure - Internal Review Draft	US EPA	1/1/87	San Diego, CA	Report	
240	Ohsaki, Y.; Abe, S.; Kimura, K.; Tsuneta, Y.; Mikami, H.; Murao, M	Lung Cancer in Japanese Chromate Workers	Thorax	1/1/78	San Diego, CA	Article	3
194	Oil and Hazardous Materials/Technical Assistance Data System	Topic: Stearic Acid		1/1/93	San Diego, CA		
241	Okubo, T. and Tsuchiya, K.	Epidemiological study of chromium platers in Japan	Res.	1/1/79	San Diego, CA	Article	9
266	Ommaya, A.K.; Corrao, P	Pathologic Biomechanics of Central Nervous System Injury in Head Impact and Whiplash	Accident and Pathology, Int'l Conference	6/6/68	Albuquerque, NM	Report	
136	OO-ALC	Specification for Flare Assembly MJU-7A/B	OO-ALC, Hill AFB	7/22/88	Albuquerque, NM	specification	20
12	OO-ALC/LIWBC	Flares and Chaff Composition - Miscellaneous Information	LIWBC, Hill AFB	10/30/91	Albuquerque, NM	Misc. Info	9
144	Pacific Northwest Lab (Cataldo, D.A.; Driver, C.J.; Ligotke, M.W.; Landis, W.G.; Norton, M.V.)	Environmental and health effects review for obscurant fibers/filaments	Pacific Northwest Labs for the US Army Armament Munitions Chemical Command	1/1/92	Oak Ridge, TN	report (hardcopy and microfiche)	82
243	Payne, W. W.	Production of cancers in mice and rats by chromium compounds	Arch. Ind. Health.	1/1/60b	San Diego, CA	Article	5

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
242	Payne, W.W.	The role of roated chromite ore in the production of cancer	Arch. Environ. Health	1/1/60a	San Diego, CA	Article	6
244	Petrille, F.L.. and S. DeFlora	Toxicity and mutagenicity of hexavalent chromium on Salmonella typhimurium	Appl. Environ. Microbiol.	1/1/77	San Diego, CA	Article	4
245	Petrilli, F.L. and S. DeFlora	Oxidation of inactive trivalent chromium to the mutagenic	Mutat. Res.	1/1/78	San Diego, CA	Article	12
247	Poaffetto, G., S. Parodi, M. DeFerrari, R. Troiano and G. Brambilla	Direct interaction with cellular targets as the mechanism for chromium carcinogenesis	Tumori	1/1/77	San Diego, CA	article	10
246	Pokrovskaya, L.V. and N.K. Shabynina	Carcinogenic hazards in the production of chromium ferro-alloys	Gig. Tr. Prof. Zabol	1/1/73	San Diego, CA	article	4
149	Rea, Bob	Chaff and Flare Materials	SAIC	2/25/93	Albuquerque, NM	memo	17
267	Rogers, A.B.; Francis, C.M.	Fire Effects on Prehistoric Sites: Hot Today, Gone Tamale	Society for California Archaeology	1/1/88	Boise, ID	Report	
93	Rothermel, Richard C.	A mathematical model for predicting fire spread in wildland fuels	Dept. of Agriculture, Forest Service, Intermountain Forest and Range	1/1/72	Boise, ID	Research Paper INT-115	40
248	Royle, H	Toxicity of chromic acid in the chromium plating industry	Environ. Res	1/1/75	San Diego, CA	article	23

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
94	Ryan, Bill C.	Potential fire behavior in California: an atlas and guide for forest and brushland managers	Dept. of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station	1/1/84	Boise, ID	General Technical Report PSW-77	15
25	SAIC (Zeimer, S.; Dunlap, B; Brandin, R.)	Predicted Deposition Rates; Environmental Effects of Chaff; Chaff Dispersion Modelling (memo)	SAIC	11/16/1989; 10/05/89	Albuquerque, NM	report and memo	23
139	SAIC and Desert Research Institute	Special Nevada Report	Dept. of Air Force, Navy, and Interior	9/23/91	Boise, ID	report	730
95	Salazar, Lucy A.; Bevins, Collin D.	Fuel models to predict fire behavior in untreated conifer slash	Dept. of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment	1/1/84	Boise, ID	Research Note PSW-370	6
97	Salazar, Lucy A.; Bradshaw, Larry S.	Changes in fire weather distribution: effects on predicted fire behavior	Dept. of Agriculture, Forest Service, Pacific Southwest forest and Range Experiment	1/1/84	Boise, ID	Research Paper PSW-174	11
249	Sano, T. and I. Mitohara	Occupational cancer among chromium workers	Japanese J. Chest Disorders	1/1/78	San Diego, CA	article	12
250	Satoh, K., Y. Fukuda, K. Torii, and N. Katsuno	Epidemiologic study of workers engaged in the manufacture of	J. Occup. Med	1/1/81	San Diego, CA	article	4
33	Sax, N. Irving; Lewis, Richard Sr., J.	Hazardous Chemicals Desk Reference	Van Nostrand Reinhold Company, NY	1/1/87	Santa Barbara, CA	Book	8/1000
167	Schuler, A.; Meadows, J.C.	Planning Resource Use on National Forests to Achieve Multiple Objectives	Journal of Environmental Management	1/1/75	Albuquerque, NM	article	16
98	Schweitzer, Dennis L.; Andersen, Ernest V.; Mills, Thomas J.	Economic efficiency of fire management9rograms at six National Forests	Dept. of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station	1/1/82	Boise, ID	Research Paper PSW-157	29

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
2	Science and Engineering Assoc., Inc.	Identifying and Evaluating the Effects of Dispensing Chaff from Military Aircraft	Strategic Air Command	12/5/89	Boise, ID	report	100
1	Science and Engineering Associates, Inc.	Identifying and Evaluating the Effects of Dispensing Chaff from Military Aircraft (Draft)	Strategic Air Command	10/6/89	Albuquerque, NM; Boise, ID	report	170
41	Science and Engineering Associates, Inc.	Environmental Effects of Air National Guard Chaff Training Activities	National Guard Bureau Environmental Division, Andrews, AFB, Maryland	12/1/90	Santa Barbara, CA; Albuquerque, NM; Boise, ID	Report	20
269	Science Applications International Corporation (SAIC)	Final Environmental Impact Statement for the U.S. Air Force in Idaho	United States Air Force	1/1/92	Boise, ID	Report	
207	Selevan, S.G.; Landrigan, P.J.; Stern, F.B.; Jones, J.H.	Mortality of lead smelter workers	American Journal of Epidemiology	1/1/85	San Diego, CA	Article	11
251	Silverstein, M.; F. Mirer; D. Kotelchuck, B. Silverstein and M. Bennett	Mortality among workers in a die-casting and electroplating plant	Scand. J. Work Environ. Health.	1/1/81	San Diego, CA	article	10
174	Sittig, M.	Handbook of Toxic and Hazardous Chemicals and Carcinogens	Noyes Publications		San Diego, CA	Handbook	
99	Stickney, Peter F.	Data base for early postfire succession on the Sundance Burn, northern Idaho	Dept. of Agriculture, Forest Service, Intermountain Research Station	1/1/85	Boise, ID	General Technical Report INT-180	121
100	Stickney, Peter F.	First decade plant succession following the Sundance Forest Fire, northern Idaho	Dept. of Agriculture, Forest Service, Intermountain Research Station	1/1/86	Boise, ID	General Technical Report INT-197	26

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Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
169	Stinson, Thomas	Rural Fire Protection Facilities					
43	Stoeppler, M. (Editor)	Hazardous Metals in the Environment	Elsevier Science Publishers	1/1/92	Santa Barbara, CA Public Library	Book, Ch.15	4
257	Strategic Air Command (SAC)	HQ Strategic Air Command, Message on Chaff	United States Air Force	11/15/91	Las Vegas< NV	Message	2
262	Strategic Air Command (SAC)	RR-170 Chaff Clearance 91-005	United States Air Force	1/7/92	Las Vegas, NV	Message	2
268	Swan, L.; Francis, C.M.	Fire and Archaeology	US Dept of Agriculture, Forest Service	1/1/89	Boise, ID	General Technical Report	
143	Systems Consultants, Inc. (Block, R.M.; Schiff, S.C.)	Effects of aluminized fiberglass on representative Chesapeake Bay marine organisms	Systems Consultants Inc. for Naval Research Lab	11/23/77	Oak Ridge, TN	report	70
47	Tactical Air Command	TACR 55-79 Chapter 7	USAF-TAC	8/6/90	Albuquerque, NM	Regulation	1
261	Tactical Air Command (TAC)	Tactical Air Command Regulation (TACR) 55-79; Aircrew/Weapons Controller Procedures for Air Operations	United States Air Force	10/23/87	Las Vegas, NV	Regulation	portions
263	Tactical Air Command (TAC)	HQ TAC Message: Self-Protection Flare Training	United States Air Force	5/2/88	Las Vegas, NV	Message	2
252	Taylor, F. H.	The relationship of mortality and duration of employment as reflected by a cohort of chromate workers	Amer. J. Public Health	1/1/66	San Diego, CA	article	11

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
32	Taylor, W. E.	Use of R6406 and R6407 for Chaff/Flare Drops, Environmental Assessment	USAF	1/19/83	Santa Barbara, CA, Albuquerque, NM	EA, AF Form 813	14
101	Tootell, Chris	Jette stocking plots: a design and methodology for uneven-ages stocking plot studies on the Flathead Indian reservation	BIA Branch of Forestry, Flathead Agency and Salish and Kootenai Tribes		Boise, ID	study	29
264	Tracor, Inc	Data on Flare Combustion Products	Tracor, Inc. and Aeronautical Systems Division,	7/1/78	Albuquerque, NM	Data sheet	1
253	Tsuda, H. and K. Kato	Chromosomal aberrations and morphological transformation in	Mutat. Res.	1/1/77	San Diego, CA	article	8
142	Tull, David A.	Wright Labs Advanced Chaff/Flare F&D	SAIC	2/22/93	Oak Ridge, TN	memo	2
254	U.S. EPA	Health Assessment Document for Chromium	Health and Environmental	1/1/83	San Diego, CA	report	
272	United Kingdom Health and Safety Executive for the Ministry of Defense	Chaff in the Environment at RAF Spadeadam	United Kingdom Health and Safety Executive for the	1/1/88	Boise, ID	Report	
8	United States Air Force (USAF)	Environmental Assessment MJU-7B Flare	USAF	1/1/89	Albuquerque, NM	EA	15
258	United States Air Force (USAF)	Air Force Regulation (AFR) 55-44: Performing Electronic Counter measures in the United	United States Air Force	12/6/78	Las Vegas, NV	Regulation	portions
259	United States Air Force (USAF)	Air Force Regulation (AFR) 55-79: Aircrew and Weapons Director Procedures for Air Operations	United States Air Force	8/17/92	Las Vegas, NV	Regulation	portions
260	United States Air Force (USAF)	Air Force Regulation (AFR) 50-46; Weapons Ranges	United States Air Force	1/1/89	Las Vegas, NV	Regulation	portions
135	USAF	Technical Order 11 A16-40-7 (MJU-7B, MJU-7A/B), 11A16-41-7 (M-206),	USAF - ACC	nd	Albuquerque, NM	technical Order	30

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
141	USAF DCS/O	Effects of Chaff on Animals	USAF SCS/O, Aircraft Test Division	6/8/73	Boise, ID	report	45
170	USDA Forest Service	Rural Community Fire Protection	Government Printing Office	1/1/77	Albuquerque, NM	summary report	12
208	Van Esch, G.J.; Kroes, R.	The inductin of renal tumors by feeding of basic lead acetate to mice and hamsters	British Journal of Cancer	1/1/69	San Diego, CA	Article	7
138	Van Gasbeck, David C.	Chaff Toxicity to Cattle-Keep	HQTACI DEEV	3/19/84	Boise, ID	report-survey	5
104	Vaux, Henry J. Jr; Gardner, Philip D.; Mills, Thomas J.	Methods for assessing the impact of fire on forest recreation	Dept. of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station	1/1/84	Boise, ID	General Technical Report PSW-79	13
191	Venugopal, B.; Luckey, T.D.	Metal Toxicity in Mammals. 2. Chemical Toxicity of Metals and Metalloids	Plenum, New York	1/1/78	Santa Barbara, CA	Book	
255	Watanabe, S.; Y. Fukuchi	An epidemiological survey on lung cancer in workers of a	Presented at International	1/1/75	San Diego, CA	report	
161	Watson, Alan; Roggenbuck, J.; Williams, D.	The Influence of Past Experience on Wilderness Choice	Journal of Leisure Research	1/1/91	Albuquerque, NM	article	14
14	Weickman, Helmut K.	Impact Statement on Lightning Suppression Project	NOAA, Atmospheirc Physics and Chemistry Laboratory	10/1/72	, and Santa Barbara	Impact Statement	6
105	Wilson, Ralph A.	A reexamination of fire spread in free-burning porous fuel beds	Dept. of Agriculture, Forest Service, Intermountain Forest and Range	1/1/82	Boise, ID	Research Paper INT-289	28

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Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
128	WR-ALC	Technical Exhibit for Chaff, Countermeasures, Type RR 72C/AL	W-R ALC, W-R AFB	3/9/87	Albuquerque, NM	specification	34
129	WR-ALC	Technical Exhibit for Chaff, Countermeasures, Type RR 185/AL	W-R ALC, W-R AFB	9/1/86	Albuquerque, NM	specification	28
130	WR-ALC	Chaff Countermeasures RR 72 B/AL	W-R ALC, W-R AFB	4/1/86	Albuquerque, NM	specification	14
131	WR-ALC	Chaff Countermeasures RR 112/AL	W-R ALC, W-R AFB	4/2/86	Albuquerque, NM	specification	14
132	WR-ALC	Chaff Countermeasures RR 149/AL	W-R ALC, W-R AFB	4/3/86	Albuquerque, NM	specification	14
133	WR-ALC	Technical Exhibit for Chaff, Countermeasures, Type RR 149A/AL	W-R ALC, W-R AFB	3/6/87	Albuquerque, NM	specification	34
134	WR-ALC	Technical Exhibit for Chaff, Countermeasures Type 112 A/AL	W-R ALC, W-R AFB	3/3/87	Albuquerque, NM	specification	40
107	Wright, H. E. Jr	Landscape development, forest fires, and wilderness management	Science, vol. 186, no. 4163	1/1/74	Boise, ID	article	8
106	Wright, Henry A.	Shrub response to fire, in Wildland and Shrubs	Dept. of Agriculture, Forest Service	1/1/72	Boise, ID	General Technical Report INT-1	14
108	Wright, Henry A.	The effect of fire on vegetation in ponderosa pine forests	Texas Tech University Range and Wildlife Information Series No 2, Dept. of Agric.	1/1/78	Boise, ID	Publication No. T-9-199	21
109	Wright, Henry A.	The role and use of fire in the semidesert grass-shrub type	Dept. of Agriculture, Forest Service,	1/1/80	Boise, ID	General Technical	24

Documents for which only a year was available, are dated 1/1/XX in this database (e.g., 1979 [month unknown] is 1/1/79).

Document Number	Author	Title	Organization	Date	Location	Document Type	Number of Pages
69		Effect of Fire on Litter and Soil Properties			Boise, ID	Research Paper	17

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APPENDIX B

Database Resources

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Database Resources

Dialog Information Services, Inc., incorporating the following databases:

- National Technical Information Center
- PTS A/DM&T, 1986-1993
- Aerospace, 1962-1993
- Commerce Business Daily, 1982-1992
- Investext, 1982-1993
- Janes Defense & Aerospace News/Analysis, 1993
- McGraw-Hill Publications Online, 1985-1993
- Business Dateline, 1985-1993
- PTS Newsletter Database, 1987-1993
- INSPEC 2, 1969-1993
- EI Compendex Plus, 1970-1993
- IHS International Standards and Specifications
- Federal Research In Progress, 1992
- Academic Index, 1976-1993
- ICC IBR, 1992

Defense Research On-Line System (DROLS)

Defense Technical Information Center (DTIC)

Toxicological, Occupational Medicine and Environmental Series (TOMES), incorporating the following databases:

- Hazardous Substances Database (HSDB)
- Registry of Toxic Effects of Chemical Substances (RTEC)
- Oil and Hazardous Materials/Technical Assistance Data System (OHM/TDS)
- Integrated Risk Information System (IRIS)

APPENDIX C

Range and Airspace Descriptions

APPENDIX C
Range and Airspace Descriptions

The following is a description of the ranges, MOAs, MTRs, Warning Areas, and other designated areas where chaff and/or flares are used by Air Combat Command aircraft. Also noted are any procedures or restrictions that have been established to supplement Air Force or Command directives.

Nellis Range Complex — The Range Complex lies to the north and northwest of Las Vegas, NV and includes R-4809, R-4808N and S, R-4807A and B, and R-4806W and E, and the Reveille and Desert MOAs. All Restricted Areas operate without time or altitude constraints except R-4806E. This area is active Monday through Saturday from 5:00 a.m. to 8:00 p.m. at altitudes from 100 ft AGL to unlimited. Both MOAs are active from 100 ft AGL to 17,999 ft, sunrise to sunset, Monday through Saturday. Both MOAs may also operate at other times with notification through NOTAM.

Chaff may be employed in all ranges and MOAs between 300 ft AGL and 25,000 ft MSL except R-63, R-65, R-74A, Wilderness Areas, Wilderness Study Areas, National Parks, and populated areas. Additional restrictions may be imposed dependent on weather conditions. All flares are authorized in the numbered and electronic combat (EC) ranges and flare use in the MOAs is limited to the MJU-7B lots marked "MBT." Flares will not be dropped over manned sites, ground parties, or within 3 nm of forested areas due to dud and residue hazards. Altitudes will be used that allow vertical drop to burn out plus 100 ft AGL. The minimum flare employment altitude in MOAs is 5,000 ft AGL and the minimum altitudes for the numbered ranges and the EC ranges are as follows:

RF-4	MJU-2	300 ft AGL
F-4, A-7, A-10	MJU-7B, 7A/B	500 ft AGL
OA-10, F-16, F-15, and F-111	MJU-10	500 ft AGL
B-1	MJU-23	500 ft AGL
B-52	ALA-17	800 ft AGL

Poinsett Range — This range is located within R-6002 approximately 5 nm south of Shaw AFB, SC. The range airspace extends from the surface to 13,000 feet MSL and is active intermittently from 6:00 a.m. to 12:00 midnight Monday through Friday and 8:00 a.m. to 4:00 p.m. on Saturdays.

Saylor Creek Range — The Saylor Creek Range is located within R-3002A which extends from the surface to 18,000 feet MSL. Two other restricted airspace segments, R-3002B and C, extend south of this range and provide an approach corridor to the target area. The Bruneau, Sheep Creek, and Owyhee MOAs surround the restricted areas and provide supporting airspace for both range and air-to-air training. The Saylor Creek Range is active 8:00 a.m. to midnight, Monday through Friday, and as required on weekends.

Nonexplosive chaff can be dropped anywhere within the Saylor Creek Range and all MOAs below 5,000 feet AGL. Explosive chaff can only be dropped within the Range impact area. Flares can be used year round and can only be dropped within the range impact area at those minimum altitudes established in TACR 55-79.

UTTR — The UTTR Range Complex is west, southwest of Salt Lake City, Utah. Chaff and flare activities are allowed only over DOD land in R-6404 west of a line running north and south along Lambert Blvd. and in R-6406A and R-6407.

Bundle/burst chaff and self-protection flares are authorized from the surface to 58,000 ft MSL (FL 580). Chaff drops will comply with pertinent FAA regulations and flares will be dropped from an altitude so as to burn out prior to impact with the ground. The restricted areas operate on a continuous basis from the surface up to 58,000 ft.

Superior Valley/China Lake Complex — There are three Restricted Areas associated with this complex, R-2505, R-2524, and R-2509. Located in the high desert north of Edwards AFB, CA. All three areas operate from the surface to unlimited altitude on a continuous basis.

NAS Fallon Ranges/MOAs — The different ranges and MOAs that make up the Fallon Range Training Complex lie to the northeast, east, and south of Fallon, NV. This airspace generally operates daily from 7:15 a.m. to 11:30 p.m. with altitudes ranging from the surface to over the ranges to 100 ft AGL in the MOAs and extending up to 18,000 ft MSL.

White Sands Missile Range — This range complex is located west of Holloman AFB, NM and includes the Red Rio, Oscura, and McGregor weapons ranges. Restricted airspace overlying these ranges extends from the surface to unlimited altitudes and is shown as being in effect continuously.

Flares are limited to use within the lateral limits of the Lava area overlying the Oscura Range and the Yonder impact area and may be dropped between 1,000 ft AGL to 50,000 ft MSL. Chaff is authorized in accordance with the chaff permit issued to the 49th Fighter Wing.

Goldwater Range Complex (Luke AFB) — The complex is located southeast of Phoenix, AZ adjacent to the Mexican border and includes R-2301E, R-2304, R-2405, and the Sells MOA. The restricted areas operate from the surface to 80,000 ft MSL in R-2301E, and to 24,000 ft MSL in R-2304 and R-2305. The Sells MOA is stratified with the lower floor at 3,000 ft AGL and the upper ceiling at 17,999 ft MSL. R-2301E is active Monday through Friday 6:30 a.m. to 10:30 p.m. R-2304 and R-2305 are active seven days per week from 7:00 a.m. to 11:00 p.m. The Sells MOA is active Monday through Friday from 6:00 a.m. to 7:00 p.m. All areas of the Goldwater Range Complex may operate at different times through NOTAM changes.

Flare use is in accordance with the altitude restrictions in TACR 55-79. The only area authorized for chaff use is R-2301E. Chaff can be dropped from the surface to 5,000 ft AGL when winds are 25 knots or less in the direction of Phoenix, and 5,000 to 15,000 ft AGL if winds are 13 knots or less towards Phoenix.

Townsend Range — Restricted Area 3007 consists of five subcomponents and is located southeast of Savannah, GA approximately 5 miles south of the Ft. Stewart ranges. Altitudes within the restricted areas vary from the surface to 13,000 ft MSL. All areas are active from 7:00 a.m. to 5:00 p.m.

Pinecastle Range — Restricted 2910 is located west of Daytona Beach, FL. The area is segmented with the center section accommodating activities from the surface to 22,999 ft MSL. Other segments contained within R-2910 operate from the surface to varying ceiling altitudes. The entire area is active daily from 5:00 a.m. to 1:00 a.m. and at other times by NOTAM.

Lake George Range — R-2907A and R-2907B are located west of Daytona Beach, FL and north of the Pinecastle Range. R-2907A operates from the surface to 22,999 ft MSL. R-2907B is in two segments and operates from the surface to 6,000 ft MSL in one segment and to 9,000 ft MSL in the second segment. All of R-2907A and B are active daily from 5:00 a.m. to 1:00 a.m.

Avon Park — R-2901, the restricted area, is located south of the Orlando Airport and is subdivided into nine areas with different altitude blocks established for each area. All but one area is under continuous operation. R-2901A operates on an intermittent basis.

Ft. Stewart Range — R-3005 is southwest of Savannah, GA and is subdivided into five areas all of which operate from the surface to 29,000 ft MSL. These areas are active seven days per week from 6:00 a.m. to midnight, with the exception of R-3005C which extends to 3:00 a.m.

Ft. Benning Range — These ranges are southeast of Columbus, GA and overlie two surface areas. R-3002A, B, and C comprise one stratified area with activities from the surface to 14,000 ft MSL. This area is active daily from 6:00 a.m. to 2:00 a.m. and at other times by NOTAM. R-3002D and E overlies a second surface area and operates with the same altitude floor, ceiling, and daily time schedule as the other area.

Melrose Range — The range is approximately 30 miles west of Clovis, NM and includes R-5104 A and B, and R-5105. R-5104 is stratified with the lower floor being ground level and the upper ceiling at 22,999 ft MSL. R-5105 operates from the surface to 10,000 ft MSL. Both restricted areas are active seven days per week from 8:00 a.m. to midnight and may operate at other times through NOTAM.

Chaff and flare expenditures are authorized within the range area at an altitude of 10,000 ft MSL or less, only with Range Control Officer approval. Aircrews will not dispense chaff when forecast winds are above 50 knots at or below their expected level of release. Minimum altitude for flare employment is 1,000 ft AGL.

W-102 — A large Warning Area off the coast of Maine. The area is stratified and operates from surface to 60,000 ft MSL at intermittent times and on intermittent days.

W-105 — This Warning Area parallels the northeastern coast from Washington, DC to Providence, RI. The area is subdivided to overlie five surface areas operating from the surface to as high as 50,000 ft MSL. The days and time of use are both on an intermittent basis.

W-107 — There are six Warning Areas within the W-107 series, W-107A, B, C, D, E, and F. All are located off the coast of Atlantic City, NJ and operate from the water surface up to an unlimited ceiling. There are two exceptions, W-107B which has a ceiling of 1,999 ft and W-107C which has a ceiling of 17,999 ft. All of these areas are active on an intermittent basis.

W-108, W-386, W-72, and W-122 are a series of Warning Areas along the eastern seaboard. These Areas extend from the Delaware Bay south to Charleston, SC and are active from the surface to unlimited altitude. Small portions of these areas such as the southwest corner of W-386, and the western portion of W-72 contain an altitude ceiling to accommodate domestic commercial air traffic.

W-151 — The four Warning Areas, 151 A, B, C, and D are directly south of Panama City, FL and operate from the surface to unlimited altitude on an intermittent day and time basis.

W-157A — This Warning Area is off the Atlantic coast, southeast of Savannah, GA and is active on a continuous basis from the surface to 43,000 ft.

W-285 — Paralleling the coast of California from San Jose to Paso Robles W-285 A and B contain the airspace from surface to 45,000 ft. Both of these areas operate Monday through Friday from 5:00 a.m. to 9:00 p.m.

W-470 — Warning Area 470 covers five surface areas of the Gulf of Mexico southeast of Panama City, FL. There are no altitude constraints on these surface to unlimited operations. Time and days of use are published as intermittent.

W-570 — This Warning Area is located off the coast of Oregon and overlies an area of the Pacific that extends south from the mouth of the Columbia River to a point approximately opposite the City of Eugene, Oregon. W-570 includes airspace from the water surface up to 50,000 ft MSL. The time of use is not consistent and is activated by NOTAM.

R-2301W — R-2301W is contiguous to the U.S./Mexico border, southeast of Yuma, AZ. The area operates 24 hours per day, 7 days per week from the surface to 80,000 ft. Although R-2301W is adjacent to R-2301E, it is not considered part of the Goldwater Range.

Powder River A&B MOAs — The MOAs are located between Miles City, MT and Rapid City, SD. Both operate on an intermittent basis activated by NOTAM. Powder River A operates from surface up to but not including 18,000 ft MSL. Powder River B operates from 1,000 ft above ground level up to but not including 18,000 ft MSL. Chaff use is confined to the MOAs below 15,000 ft AGL and is used for air-to-air engagements only. Flares are not used.

Pecos MOA — The MOA lies west of Clovis, NM and adjoins the western boundary of R-5104A. The MOA is stratified with designations of Low and High. Pecos Low altitude boundaries are from 500 ft AGL up to 10,999 ft MSL and operates on an intermittent basis with notice of activities by NOTAM. Pecos High is structured to operate from 11,000 ft MSL to 17,999 ft MSL with activities occurring Monday through Friday, sunrise to sunset. Pecos High may also operate at other times with notification by NOTAM.

Saylor Creek MOA — The Saylor Creek MOA is located southeast of Twin Falls, ID within the Mountain Home AFB range complex. Hours of operation are daily from 6:00 a.m. to 2:00 a.m. The MOA is active from 100 ft AGL to 14,500 ft.

Tiger MOA — The Tiger North and South MOAs are contiguous and are northeast of Minot, ND and northwest of Grand Forks, ND. These MOAs are directly south of the Canadian border and are operated on an intermittent basis through NOTAM. Tiger North activities are carried out from 300 ft AGL up to 17,999 ft MSL. Tiger South operating altitudes are from 6,000 ft up to 17,999 ft MSL.

Hays MOA — This airspace overlies an area triangulated by the cities of Havre, Glasgow, and Lewistown, MT. The MOA contains airspace from 300 ft AGL up to 17,999 ft MSL. The MOA operates on an intermittent basis and is activated by NOTAM.

ADA MOA — This MOA is located north of Salina, KS extends from 7,000 ft MSL up to but not including 18,000 ft MSL. Its published times of use are days, Monday through Friday and occasionally on weekends.

Salem MOA — This MOA is located south of St. Louis, MO and extends from 100 ft AGL to but not including 8,000 ft MSL. It is used intermittently as activated by NOTAM.

Ellsworth Chaff Area — This large area covers the western half of Montana and Wyoming, two-thirds of each of the States of North and South Dakota, and slightly less than one-half of the State of Kansas. The clearance for the use of this area authorizes daily use with chaff drops from 500 ft AGL to 25,000 ft MSL.

Loring Chaff Areas — These are three locally designated corridors along a route on which Loring B-52s drop chaff. Two of the areas are east of Griffiss AFB where chaff drops occur at 28,000 ft MSL (FL 280) and the third is just west of Bangor, ME where drops are at 17,000 ft MSL.

APPENDIX D

Laws, Regulations, and Citations

APPENDIX D
Laws, Regulations, and Citations

National Environmental Policy Act of 1969, P.L. 91-190, 42 USC 4321-4370a

Council on Environmental Quality NEPA Regulations, 40 CFR Part 1500-1508; AFR 19-2

Clean Air Act; 42 USC 7401 et. seq.; P.L. 90-148 (1970)

Clean Air Amendments (1990), P.L. 101-549 (codified in 42 USC 7401 et.seq.)

EPA Clean Air Regulations, 40 CFR Parts 50-87

Clean Water Act, 33 USC 1261 et.seq.

EPA Clean Water Regulations, 40 CFR 104-501; Part 122 (NPDES)

Weinberger v. Romero-Barcelo, 456 U.S. 305 (1982)

Marine Protection, Research, and Sanctuaries Act of 1972, 33 USC 1401-1445

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, P.L. 93-254

EPA Ocean Dumping Regulations, 40 CFR 227-228.

Resource Conservation and Recovery Act, 42 USC 6901 et.seq.

EPA RCRA Regulations, 40 CFR 200-268; 270-272; 280-81

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund), 42 USC 9601 et.seq.

EPA CERCLA Regulations at 40 CFR 300-373.

EPA Solid Waste Disposal Guidelines, 40 CFR 240.100

Endangered Species Act, P.L.93-205; 16 USC 1531-1544;

DOI ESA Regulations, 50 CFR 450-452

Marine Mammals Protection Act, P.L. 95-522; 16 USC 1361-1407

DOI MMPA Regulations, 50 CFR 220-230

Migratory Bird Treaty Act; 16 USC 701 et.seq

DOI Regulations implementing MGTA, 50 CFR Part 21

Wilderness Act, P.L.88-577; 16 USC 1131-1136

Air Commerce Act of 1926, 44 Stat. 568 (since repealed by the Federal Aviation Act of 1958

Federal Aviation Act of 1958, P.L. 85-726; 49 USC App. 1301 et seq.

FAA Regulations on Air Traffic, 14 CFR 91-93; on Airspace (500 foot rule at 91.119); 71-73 (Special Use Airspace at 73)

Federal Land Policy and Management Act of 1976 (FLPMA or the BLM Organic Act), 43 USC 1701 et.seq (land withdrawals at 1714; management and denial of special use permits for military activities at 1732)

Engle Act, 43 USC 155-158

Coastal Zone Management Act, P.L.92-583; 16 USC 1451-1454;

NOAA Coastal Zone Regulations 15 CFR 921-933

AFR 50-46, Weapons Ranges (1-13c. on chaff and flare use)

ACC Regulation 55-79

Federal Tort Claims Act, 28 USC 1346; 28 USC 2671-80

AFR 112-1, Claims

Peterson v. United States, 673 F.2d 237 (7th Cir. 1982)

U.S. Constitution, Amendment V, Just Compensation Clause

Tucker Act, 28 USC 1491(a)

E.O. 12630, March 18, 1988

Maynard v. U.S., 430 F.2d 1264 (9th Cir 1970)

The Military Claims Act, 10 USC 2731-2737

U.S. v. Causby, 328 U.S. 256 (1946)

Branning v. U.S.

10 USC 2672, Minor Land Acquisitions

U.S. v. Dahlehite, 346 U.S. 515 (1953)

APPENDIX E

Supplemental Toxicological Data

APPENDIX E
Supplemental Toxicological Data

The primary source of the following toxicological information was obtained primarily from the TOMES database which comprises twelve different databases, including the HSDB, RTEC, OHM/TDS, and IRIS. Other references are provided in Appendix A.

Chromium

Chromium exists in six valence states. Chromium species, including hexavalent chromium, are quite soluble and are not absorbed to the common environmental matrixes such as clays, hydrous metal oxides, and biological substances. However, Cr VI can be effectively removed in the presence of activated carbon. Chromium VI is a moderately strong oxidizing agent and it reacts to form Cr III which is subsequently hydrolyzed to form $Cr(OH)_3$. In the atmosphere, chromium is predominantly associated with suspended particulates. Chromium bearing aerosols are transported long distances before settlement. However, the dynamics of transport and distribution of chromium-containing particulates is not clearly understood.

Following intratracheal administration, water soluble chromates disappear from lungs while the trivalent chromic chloride remains largely in the lower respiratory tract. Absorption through the gastrointestinal tract is rapid and depends on the presence of Cr VI, which increases absorption. Chromium normally deposits in the lungs, skin, muscle, and fat. However, chromates are bound predominantly to the red blood cells. Urinary excretion accounts for about 80% of the total chromium recovery. However, elimination through the intestine may also play a role in chromium excretion. Milk is another route of chromium excretion.

Occupational exposure to Cr VI causes dermatitis, penetrating ulcers on the hands, forearms, perforation of the nasal septum, inflammation of the larynx and liver. Although dermatitis is considered to be an allergic response, ulceration is believed to be due to Cr III. Chromic acid and chromates are presumably the causative agents in the perforation of nasal septum. It is relevant to note that skin lesions, as a rule, are not a site of cancer.

Trivalent chromium is an essential element in animals. It is considered to play a role in glucose and lipid metabolism. Chromium deficiency mimics clinical symptoms characteristic of diabetic mellitus.

Determination of the oral RfD for chronic exposure to Cr VI was based on a 1-year study on rat (IRIS 1990; MacKenzie et al. 1958). The oral RfD for Cr VI is estimated at 5E-3 mg/kg/day. Estimation of a reference dose for chronic inhalation exposure to Cr VI is currently under review at EPA.

The oral Reference dose for Cr III was estimated at 1E+0 mg/kg/day based on a rat chronic feeding study (IRIS 1990; Ivankovic and Preussmann 1975).

Chromium VI is classified by the EPA under category A, meaning it is a human carcinogen (IRIS 1990). This is based on sufficient and consistent evidence of Cr VI carcinogenicity from epidemiological studies of chromium-exposed workers (Machle and Gregorius 1948; Brinton et al. 1952; Mancuso and Hueper 1951, Mancuso 1975; Baetjer 1950a,b; Taylor 1966; Enterline 1974; Hayes et al. 1979; Hill and Ferguson 1979; Bidstrup 1951; Bidstrup and Case 1956; Alderson et al. 1981; Watanabe and Fukuchi 1975; Ohsaki et al. 1978; Sano and Mitohara 1978; Satoh et al. 1981; Korallus et al. 1982; Bittersohl 1971). Dose-response relationships have been established for chromium-induced lung cancer. Although epidemiological data is sufficient for Cr III and lung cancer, experimental data on Cr III as a carcinogen are largely negative.

Lead

Metallic lead and common lead minerals are insoluble in water. However, several industrially produced lead compounds are readily soluble in water (EPA 1984). Lead forms insoluble complexes with carbonate or sulfate ions or ferric hydroxide limiting its mobility. However, inorganic and organo-lead compounds are primarily transported as particulates in the atmosphere. Transport of lead in aquatic environment is influenced by the oxidation states of lead. Lead exists as a divalent cation in unpolluted water. However, organic complexation is critical in polluted waters.

Bioaccumulation of lead is reported in a variety of organisms, and bioaccumulation factors are in a range of 100 to 1000. Biotransformation to a methylated form by microbes can remobilize lead in the environment.

The absorption of lead from the gastro-intestinal tract is regulated to some extent by the mechanism regulating calcium and phosphorus absorption. It is estimated that approximately 37% of the inhaled lead is retained in the lungs. However, this estimation has several variables such as particle size, composition, respiration rate, etc.

Once absorbed, lead selectively accumulates in the bone. It is estimated that 90% of the lead body burden is found in the bone followed by aorta, liver, kidney, and pancreas. Lead remains loosely bound to the red blood cells while in circulation.

Numerous studies have been done on the general toxicity of lead. Acute inorganic lead intoxication is rare among adult humans but may occur, especially in children. Manifestations of acute lead poisoning include nausea, vomiting, metallic taste, and circulatory collapse. These are followed by muscular weakness, acute hemolytic anemia and renal damage. Short-term exposure to lead can cause reversible kidney damage, but prolonged exposure at high concentrations may result in progressive kidney damage and failure. Chronic exposure to inorganic lead has distinct toxicological effects. Among gastro-intestinal manifestations, colic is particularly characteristic of chronic lead intoxication.

Lead and several lead salts are carcinogenic in experimental animals. Renal tumors in rodents have been reported following parenteral administration of lead. However, the data on the carcinogenicity of lead on humans are inconclusive.

Lead is classified as a B2 carcinogen by the EPA (IRIS 1990). Weight-of-evidence for such a classification was based on the availability of sufficient evidence from animal studies, where rat bioassays and one mouse assay have shown statistically significant increases in renal tumors with dietary and subcutaneous exposure to several soluble lead salts. Animal assays have provided reproducible results in several laboratories, in multiple rat strains with some evidence of multiple tumor sites. Short-term studies show that lead affects gene expression. However, human carcinogenicity evidence is inadequate.

Due to the prevalence of several uncertainties, quantitative estimate of carcinogenic risk from oral exposure to lead is not currently available. Likewise, quantitative estimates of carcinogenic risk from inhalation exposure are not available.

APPENDIX F

Air Force Regulation 127-4, Investigating and Reporting U.S. Air Force Mishaps
Mishap Categories and Classes

APPENDIX F
Air Force Regulation 127-4,
Investigating and Reporting U.S. Air Force Mishaps
Mishap Categories and Classes

According to AFR 127-4, paragraph 2-3, Air Force mishaps are categorized by the environment in which they occur. This allows processing by safety and medical staff personnel who specialize in these mishap environments. Also, statistics on mishap experience may be broken down into environmental categories for better understanding. These categories include:

- Aircraft Mishaps. These are mishaps involving Air Force aircraft.
  - Flight Mishaps. These are mishaps involving Air Force aircraft when intent for flight is established.
  - Flight Related Mishaps. These are mishaps in which external stores are unintentionally dropped from an aircraft without reportable damage to the aircraft.
  - Aircraft Involved Mishaps. These are mishaps that involve aircraft. Add the term aircraft involvement in parentheses after the primary category. Examples include Ground (Aircraft Involvement), Explosives (Aircraft Involvement), FOD (Aircraft Involvement), Missile (Aircraft Involvement), etc.
- Foreign Object Damage (FOD) Mishaps. These are mishaps where reportable engine damage is caused by FOD. Use this category only when damage is confined to the engine or integral engine components, (i.e., engine mounted accessory gear boxes and plumbing [does not include cowlings]). If engine parts exit the engine and cause less than reportable damage external to the engine, then use the FOD category. If engine parts exit the engine and cause reportable damage, then report in the appropriate category other than FOD.
- Missile Mishaps. These are mishaps involving missiles or missiles support equipment.
- Explosives Mishaps. These are mishaps involving explosives, explosive devices, or chemical agents.
- Ground Mishaps. These are mishaps not defined in other nonnuclear categories. These are mishaps that occur on ground or water — on or off an Air Force installation — involving Air Force personnel, Air Force contractor operations, or Air Force property.

- Nuclear Mishaps. These do not apply to chaff and flares use.

- Space Mishaps. These are mishaps involving space systems or their support equipment (not applicable to chaff and flares use).

AFR 127-4, paragraph 2-4 outlines mishaps classes. These include Class A-D and High Accident Potential. These are defined as:

- Class A Mishap. A mishap resulting in a total cost of $1 million or more for property damage; a fatality or permanent total disability; or destruction of, or damage beyond economical repair to an Air Force aircraft.

- Class B Mishap. A mishap resulting in a total cost of $200,000 or more, but less than $1 million for property damage; a permanent disability; or hospitalization of five or more personnel.

- Class C Mishap. A mishap resulting in a total damage that costs $10,000 or more, but less that $200,000; an injury or occupational illness that results in a lost work-day case involving days away from work (8 hours or greater); or a mishap that does not meet the criteria above, but which AFR 127-4, Chapters 5-9 requires reporting.

- Class D Mishap. A mishap resulting in a total damage that costs $2,000 or more, but less than $10,000; a lost workday case involving more than 1 but less than 8 hours; a nonfatal case without lost workdays; or a mishap that does not meet the criteria above, but which AFR 127-4, Chapters 5-9 require reporting.

- High Accident Potential. These are aircraft, missile, space, explosive, or ground events that have a high potential for causing injury, occupational illness, or damage if they should recur. These events may or may not have reportable mishap costs. If the total cost of a mishap is less than Class C criteria, do not designate it as a Class C mishap, and do not include the cost in the report. Report High Accident Potential mishaps per paragraph 4.3d.