# Operational Risk Analysis of Predator/Reaper Flight Operations in a Corridor between Cannon AFB and Melrose Range (R-5104A)

## Executive Summary

This assessment was prepared to support the 27th Operations Group application for a Certificate of Authorization (COA) in support of Air Force Special Operations Command (AFSOC) Predator/Reaper Unmanned Aircraft Systems (UAS) operations at Cannon AFB, NM. AFSOC took control of Cannon AFB in October of 2007 and this expansion offers Special Operators a western U.S. base to enhance support for operations in the Pacific theater and meet the objectives of our global defense posture. The Predator and Reaper are invaluable DoD assets in the Global War on Terrorism and it is of utmost importance to the National Security that our pilots be able to train and maintain proficiency. This document includes a MQ-1 ground observer capability demonstration (attachment 1), a UAV FY 2008 hazardous aircraft traffic report spreadsheet, and a Cannon AFB aircraft control radar log of all observed radar traffic operating in the vicinity of the proposed corridor.

Predator operations within Cannon's Class D airspace are anticipated to begin in March 2009. A COA (ASN-2008-CSA-10) has been approved by the Federal Aviation Administration (FAA) for the Predator operations within the Cannon AFB Class D airspace. Reaper operation dates at Cannon are still to be determined due to the on-going priorities overseas.

The next step is to provide pilots and crew members a proposed corridor between Cannon AFB and R-5104 so that they can access needed airspace for realistic "train the way you fight" continuation and proficiency training. To that end, a corridor has been designed (figure 1) and a risk assessment was completed in accordance with AFI 90-901, *Operational Risk Management*, to present data to show that AFSOC has sufficiently mitigated the risk of a potential collision between an unmanned aircraft and an uncooperative (no transponder) aircraft. The Air Force six-step ORM process is a sound methodology for risk assessment, and the process provides formal documentation of acceptance of residual risk at the appropriate level.

UAS operations within the 27th Special Operations Wing (SOW) will soon expand to include a second UAS, the MQ-9 Reaper. Historical, empirical data referenced in this assessment relied on MQ-1 Predator and available MQ-9 data. Since MQ-1 and MQ-9 operations are comparable, recommendations and conclusions here apply to these unmanned aircraft system airframes operated by the 27th SOW.

The USAF has applied risk management philosophy and methods to Predator operations intuitively and experientially for years. Declining mishap rates in the ground, flight and weapons arenas are the result of these risk management efforts. Applying a structured ORM process allows greater and more consistent results by using a systematic method rather than relying solely on experience.

AFSOC convened subject matter experts from the staff along with FAA participation and representation from the 27th SOW. The group reviewed planned Predator operations in the proposed corridor using a variety of approved ORM tools listed in AFMAN 90-902, *Operational*

*Risk Management Guidelines and Tools*, to complete a thorough assessment which included all six steps required in the ORM process:

- Identify the Hazards: apply appropriate hazard identification techniques to identify hazards associated with the proposed operation or activity.

- Assess the Risk: apply quantitative or qualitative measures to determine the probability and severity of adverse outcomes associated with exposure to identified hazards.

- Analyze Risk Control Measures: evaluate specific strategies and controls that reduce or eliminate risk. Effective mitigation measures reduce one of the three components (probability, severity or exposure) of risk.

- Make Control Decisions: choose the best control or combination of controls based on the analysis of overall costs and benefits, and formally accept any residual risk.

- Implement Risk Controls: once control measures have been selected, an implementation strategy must be developed and carried out.

- Supervise and Review: leaders at every level must fulfill their respective roles in ensuring controls are sustained over time; once controls are in place, the process must be periodically re-evaluated to ensure its effectiveness.

This ORM assessment resulted in the following conclusions:

1. AFSOC is able to safely conduct Predator flight operations within the proposed corridor.

2. AFSOC has implemented mitigating actions to address the shortfalls of unmanned aircraft with respect to 14 CFR Part 91.

3. The risk mitigation in place results in a residual risk level of ***Medium*** in accordance with governing Air Force guidance. This equates to a level of "extremely remote" in accordance with FAA guidance. The primary hazards contributing to the risk of mid-air collision and loss of aircraft or loss of life have been considered and mitigated. In accordance with guidance in AFI 90-901 and the AFSOC supplement, this level of risk may be accepted at the Squadron Command level. This assessment is prepared for AFSOC/A3 review to document command acceptance and approval of the ORM process.

4. Predator operations must be periodically reviewed to verify that previously instituted mitigation measures are validated and remain effective.

5. Predator operations must be periodically reviewed when technological solutions become available to further mitigate risk. Technological solutions should not be mandated, but systematically reviewed to determine when it is economically feasible and mission supportive.

6. The implemented mitigation measures support the 27th OG application for a COA in support of AFSOC operations in a corridor between Cannon AFB and R-5104A.

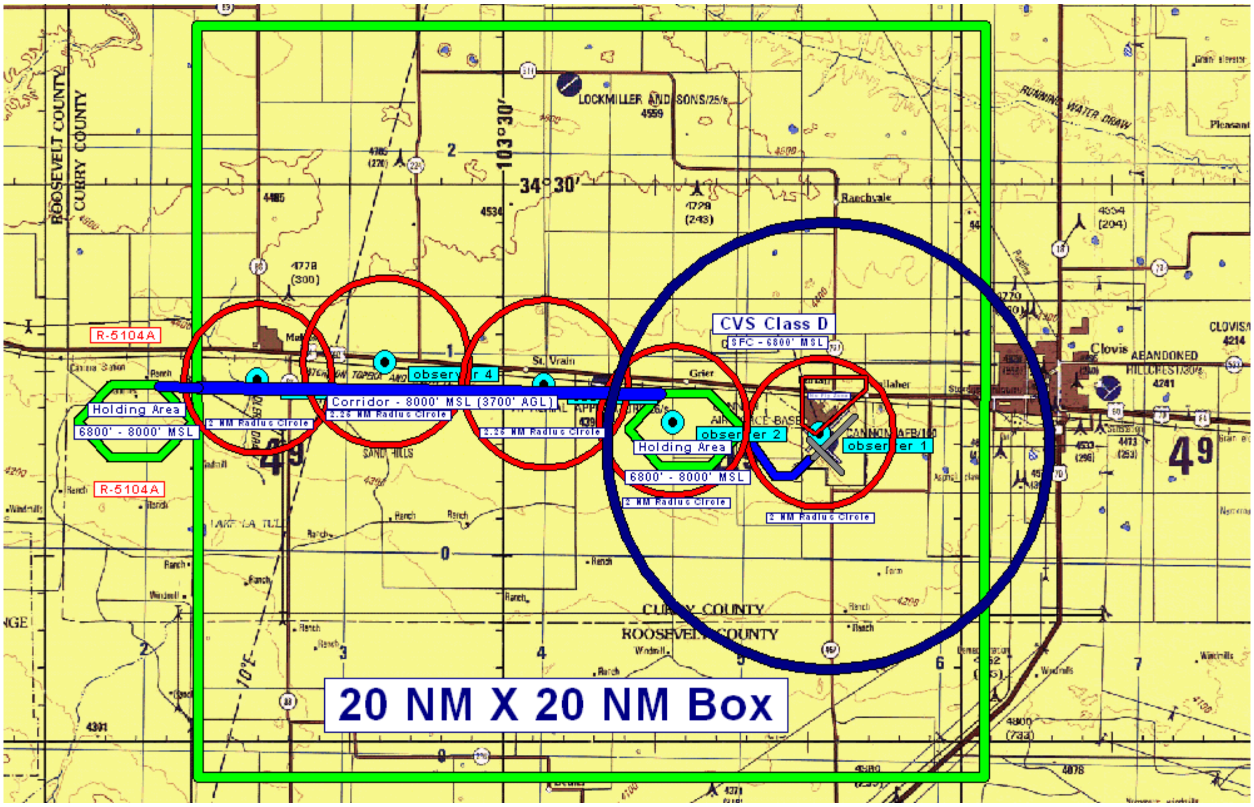


Figure 1. Proposed Corridor.

**Hazard Analysis**

**ACTIONS FOR STEP 1 – IDENTIFY THE HAZARDS**

**ACTION 1: MISSION/TASK ANALYSIS** → **ACTION 2: LIST HAZARDS** → **ACTION 3: LIST CAUSES**

Hazard identification is the foundation of the ORM process. Hazards were identified as associated with the following three categories IAW AFMAN 90-902: Mission Degradation, Personal Injury or Death, and Property Damage. This analysis focused on hazards associated with potential mid-air collision between an unmanned aircraft and both cooperative and non-cooperative aircraft within a defined corridor between Cannon AFB and R-5104A. Formal hazard identification tools included Operational Analysis and Preliminary Hazard Analysis, and Logic Diagrams. Mission/Task Analysis was accomplished through a review of current and planned Cannon AFB Predator operations, as well as a thorough review of mishap data from the FAA, NTSB, and Air Force Safety Automated System (AFSAS). Current guidance was reviewed including applicable Air Force Instructions, FAA regulations, operating instructions, checklists, briefing guides, syllabi, FCIFs, NOTAMs, and policy letters. Major mission tasks were grouped into subsets based on mission phase and charted in time sequence with hazards, and factors that could generate hazards, identified based on the deficiency to be corrected and mission and system requirements. This yielded a listing of inherent hazards or adverse conditions which could contribute to the possibility of a midair collision. Analysis also examined interfaces between or among individual elements. Major mission phases included the mission planning phase, takeoff through departure, enroute maneuvering, return to base, traffic pattern operations, and post-flight.

Following the Operational Analysis, the group completed a Preliminary Hazard Analysis (PHA) to consider risk in the major mission phases and to prioritize follow-on hazard analyses. The PHA produced three groups of hazards for follow on study divided into mission planning hazards, external hazards, and in-flight hazards as summarized in table 1 below.

| **Preliminary Hazard Analysis** | | |
|---|---|---|
| **Mission Planning Hazards** | **External Hazards** | **In-Flight Hazards** |
| 1. UAS systems failures | 1. Weather/Wind/Icing | 1. Conflict with other traffic |
| 2. Improper Command link settings | 2. Improper Route Planning/Scheduling | 2. UAS Mechanical failure |
| 3. Improper Communication system settings | 3. Failure of Air Traffic Control Radar | 3. UAS Software failure |
| 4. Inadequate Information display systems | 4. Failure of Air Traffic Control Communications | 4. Failure of Command Link |
| 5. Improper Mission Plan development | | 5. Conflict during execution of lost link procedures |
| | | 6. Position error |

**Table 1: Preliminary Hazard Analysis**

From the PHA, hazards which could contribute to a midair collision were mapped into a logic diagram to illustrate the connectivity and linkages between hazards (see Figure 2).

Results of the hazard analysis were reviewed using the 5 M model as a framework. This team focused on a successful Predator mission and potential failures that could result in a midair collision. The 5-M’s stand for Man, Machine, Media, Management, and Mission. Man, Machine, and Media interact to complete a successful Mission. Management provides the procedures and rules governing the interactions between the various elements. Each element provides opportunities to manage risk. Groups of “machine” related systems failures (**A**) and “man” related pilot procedure errors (**B**) are common to both unmanned and manned aircraft in a potential mid-air collision scenario. However, absence of a pilot in the aircraft requires that these failures and errors are addressed in different ways. The hazard analysis produced a list of specific areas in each element that could contribute to a break down in the ability to see or detect a potential collision and to take action to maneuver or avoid the conflict through other means.

## Risk Assessment

**ACTIONS FOR STEP 2—ASSESS THE RISK**

**ACTION 1: ASSESS HAZARD EXPOSURE** → **ACTION 2: ASSESS HAZARD SEVERITY** → **ACTION 3: ASSESS PROBABILITY** → **ACTION 4: COMPLETE RISK ASSESSMENT**

Risk assessment associates "hazards" with "risks". The various impacts of hazards were evaluated together with the likelihood of occurrence to produce a measurement of risk. Risks were then ranked into a priority order. Risk assessment examines three key aspects of risk: probability, severity, and exposure. Risk ranking requires making the best possible estimate of the probability, severity, and exposure of a risk compared to the other risks that have been detected. This relationship is illustrated in the risk assessment matrix below based on severity and probability categories defined IAW AFPAM 90-902.

Extremely High
High
Medium
Low

| Severity \ Probability | A Frequent | B Likely | C Occasional | D Seldom | E Unlikely |
|---|---|---|---|---|---|
| I Catastrophic | 1 | 2 | 6 | 8 | 12 |
| II Critical | 3 | 4 | 7 | 11 | 15 |
| III Moderate | 5 | 9 | 10 | 14 | 16 |
| IV Negligible | 13 | 17 | 18 | 19 | 20 |

| | |
|---|---|
| **Severity** | |
| CATASTROPHIC | Complete mission failure, death, or loss of system |
| CRITICAL | Major mission degradation, severe injury, occupational illness or major system damage |
| MODERATE | Minor mission degradation, injury, minor occupational illness, or minor system damage |
| NEGLIGIBLE | Less than minor mission degradation, injury, occupational illness or minor system damage |
| **Probability** | |
| FREQUENT | Continuously experienced in a fleet, or often in the life of a system |
| LIKELY | Occurs regularly in fleet, or several times in the life of the system |
| OCCASIONAL | Occurs several times or *will* occur in the life of the system |
| SELDOM | Can be expected to occur or *may* occur in the life of the system |
| UNLIKELY | Unlikely but could occur in the life of the system |

**Figure 2: AFSOC Risk Assessment Matrix**

Probability has been determined through a combination of estimates and actual numbers, when available. Severity levels were assigned based on the most reasonable, credible mishap scenario involving the given hazard. Probabilities in this assessment are based on System Safety Assessments, USAF mishap reports, FAA mishap data, historical reports of Predator flight hours, and subject matter experts chosen for experience with the mission and hazards. Some source data is protected from disclosure through Safety privilege as specified in AFI 91-204 or through contractor proprietary data. Systems reliability requirements were reviewed and compared to historical mishap data. Weather analysis considered conditions that might alter flight routes or altitudes or impact mission effectiveness, and included flight mishaps where weather was a factor. Air traffic control surveillance and communication assessment is based on reported equipment reliability. Assigning a quantitative level of risk of a midair collision between a UAS and a civil aircraft is challenging due to the lack of a defined level of safety required and the lack of the sample size for flights conducted within restricted areas and military operating areas in CONUS, there are relatively low numbers of reported mid-air or near mid-air events. A qualitative probability may be derived from research, analysis, and evaluation of historical safety data from similar missions and systems. Actual probabilities are influenced by mitigating procedures already in place.

The most significant hazard considered during this assessment is the potential for midair collision between an Unmanned Aircraft and other air traffic. The probability of exposure to midair collision risk associated with operations in the vicinity of Cannon AFB and R-5104A must be assessed relative to exposure to similar risk in the entire National Airspace System (NAS). This approach was chosen for several reasons. First, the limited scope of Predator operations at Cannon AFB represents a very small sample size and does not accurately represent the hazard to general aviation. Second, the burden of proof for COA approval rests on the ability to provide an "equivalent level of safety" expressed in FAA Order 7610.4M as "comparable to see-and-avoid requirements for manned aircraft." See-and-avoid is the overarching responsibility of each person operating an aircraft in accordance with 14 CFR Part 91. A valid comparison must include the relative level of exposure to the risk of midair collision to General Aviation or Commercial Carriers in the NAS. Third, this approach is consistent with previous research on hazards associated with integrating UASs into the NAS, including modeling and simulation based on accepted research methods and documented proposed mitigation options. Finally, this analysis will provide a baseline for future assessments.

The NAS infrastructure includes all federal airways, navigational aids, airports, surveillance, and air traffic control service facilities and the procedures, regulations, and personnel comprising the United States air transportation system. The system is governed by law and 14 CFR, which address both the design and operation of aircraft within the system.

The FAA System Safety Handbook (SSH) identifies levels of likelihood and severity similar to Mil Standard 882 and the AFSOC Risk Assessment matrix. The FAA also addresses likelihood of (failure) occurrence in advisory circulars for various types of aircraft, but the definitions for likelihood vary by aircraft type. The SSH and both Part 23 and Part 25 severity definitions range from probable to extremely improbable, but the numerical values assigned to those definitions is not consistent. The most restrictive values are contained in the SSH.

Using the AFSOC matrix, the unmitigated risk of midair collision is assessed as "High." A mid-air collision could potentially result in loss of an aircraft, UAS, or a fatality, and may reasonably be expected to occur within the life of the system. Comparing the AFSOC matrix definitions to the SSH, equates to a classification of extremely remote, since the event could result in fatalities or loss of a system, and may occur in the life of an entire system or fleet. The FAA SSH assigns a numerical value to this classification as less than $10^{-7}$.

One recent study by Roland Weibel and R. John Hansmann entitled "Safety Considerations for Operation of Unmanned Aerial Aircrafts in the National Airspace System" examined NTSB midair collision data for general aviation and air carrier aircraft to establish a baseline for comparison. That data, based on a review of midair collision data over 10 years, from 1991-2002, indicated that "general aviation has experienced midair collision rates on the order of $5 \times 10^{-7}$, with a decline to $2 \times 10^{-7}$ collisions per hour of operation over the last two years of the sample."[1]

The same study performed a quantitative analysis to examine comparative risk for UAS operations in the NAS. While there is still no regulatory standard guidance for a required level of safety for UASs, this analysis helps to assess an equivalent level of safety and to provide a basis of comparison for mitigation. Weibel's analysis used a gas collision model to determine the expected number of collisions per flight hour. Flight operations were examined in the airspace as a whole, from surface to 50,000 ft, including jet routes and victor airways. Manned aircraft avoid midair collision through combination of air traffic control separation and pilot ability to see and avoid other aircraft. However, the model assumed no traffic avoidance maneuvering and no positive control. The study identified a baseline level of safety and/or expected risk of midair collision on the order of $10^{-5}$ collisions per hour on major flight levels and on airways, and off major flight levels and off airways of $10^{-7}$ collisions per hour. The model suggested that "without mitigation, the ambient collision risk is on the order of $10^{-7}$, which is the currently experienced rate of midair collisions in general aviation aircraft."[2]

A review of Predator mishap reports from FY 2007 from the Air Force Safety Automated System (AFSAS) 8 Class E Hazardous Air Traffic Reports (HATRs) attachment 3. All HATR events occurred during deployed operations where the operating restrictions and procedural mitigation measures identified in section three of this report were not in place. These 8 incidents occurred over a period of 79,177 flying hours. Further analysis of these incidents reveals that all occurred in congested airspace. 4 HATRs were attributed to task saturation of air traffic controllers, 2 were attributed to poor radio coverage, and 2 were attributed to UAS pilot error. Of the two pilot errors, both occurred during inclement weather that would have precluded operations in a non-combat environment. These findings are important factors in conjunction with the uncongested nature of operations in the vicinity of the proposed corridor, low task saturation of airspace controllers, excellent radio and radar coverage of the area, and conservative local operating weather directives in place locally at Cannon AFB.

The review of research material, midair collision modeling, mishap history and procedural guidance supports the assessment for the *unmitigated* risk of midair collision. UAS operations are exposed to the same overall (ambient) collision risk and ATC separation as other aircraft operating in the NAS. Where mitigation measures are in place, there have been no recorded traffic conflicts meeting reporting criteria, while general aviation aircraft have experienced midair collisions on the order of $10^{-7}$. A target level of safety remains undefined due to lack of regulatory guidance; however, the data supports the statement that the risk of a midair collision between a UAS and a civilian aircraft is within the most restrictive FAA guidance from the SSH on the target level of safety for hazardous events. Using the FAA definitions, this data equates to a level of likelihood of “Extremely Remote.” Mitigation measures will further decrease likelihood of occurrence.

The product of the risk assessment process is a prioritized list of hazards and corresponding levels of risk (Table 2). Risks were ranked from most serious to least serious and labeled with their significance to show relative priority of the risks and their individual significance in relation to the overall objective of addressing the potential for midair collision.

| **Risk Assessment** | | | |
|---|---|---|---|
| **HAZARD** | **PROBABILITY** | **SEVERITY** | **RISK LEVEL** |
| 1. Conflict with other traffic | Seldom | Catastrophic | High (8) |
| 2. Conflict during execution of lost link procedures | Seldom | Catastrophic | High (8) |
| 3. Weather/Wind/Icing | Occasional | Critical | High (7) |
| 4. Failure of Command Link | Likely | Moderate | Medium (9) |
| 5. UAS Mechanical failure | Seldom | Critical | Medium (11) |
| 6. UAS Software failure | Seldom | Critical | Medium (11) |
| 7. Failure of Air Traffic Control Radar | Seldom | Moderate | Low (14) |
| 8. Failure of Air Traffic Control Communications | Seldom | Moderate | Low (14) |
| 9. Improper Route Planning/Scheduling | Seldom | Moderate | Low (14) |
| 10. Improper Mission Plan development | Unlikely | Critical | Low (15) |
| 11. UAS systems failures | Unlikely | Critical | Low (15) |
| 12. Improper Command link settings | Unlikely | Critical | Low (15) |
| 13. Improper Communication system settings | Unlikely | Critical | Low (15) |
| 14. Inadequate Information display systems | Unlikely | Critical | Low (15) |
| 15. Position error | Unlikely | Moderate | Low (16) |

Table 2: Risk Assessment

## Analysis of Controls and Mitigations

**ACTIONS FOR STEP 3—ANALYZE CONTROL MEASURES**

| ACTION 1: IDENTIFY CONTROL OPTIONS | → | ACTION 2: DETERMINE CONTROL EFFECTS | → | ACTION 3: PRIORITIZE RISK CONTROL MEASURES |
|---|---|---|---|---|

Risk control options include: ***rejection, avoidance, delay, transference, spreading, compensation,*** and ***reduction***. *Rejection* of risk is an option if the overall cost of the risk outweighs potential mission benefits. *Avoiding* risk altogether is not feasible due to mission importance. It is possible to avoid specific risks through scheduling or limiting operations to specific areas. *Delaying* risk may be an option while waiting on affordable and available technology integrating UAS operations into the NAS. In this situation, there is a need to continue conducting operations; delaying risk is not feasible. *Transference* of risk does not apply to this case, since the specified risk only applies to the two entities that might be involved in a potential midair collision. Risk may be *spread* out by either increasing the exposure distance or by lengthening the time between exposure events. The number of events will be driven by the number of sorties scheduled and sortie duration. There are mitigation options available in the remaining categories of compensation and reduction. *Compensation* measures include redundant capabilities that can be used to reduce risk resulting from the inability to see and avoid. *Risk reduction* involves targeting the individual components of risk: probability, severity, or exposure. The desired order of precedence from AFMAN 90-902 for dealing with hazards and reducing the resulting risks is to *Plan or Design for Minimum Risk, Incorporate Safety Devices, Provide Warning Devices, and Develop Procedures and Training*.

Some mitigation options begin within the category of planning or designing for minimum risk. As tools have become available to improve awareness of crew in the Ground Control Station (GCS), these tools have been integrated into operating procedures. In accordance with standard risk management practices, where it is impractical to eliminate hazards through design or to reduce the associated risk with safety and warning devices, procedures and training have been used. These practices together with technological solutions continue to be part of the risk management equation for Predator operations.

Significant mitigation measures will be implemented for UAS operations at Cannon AFB and R-5104A . The mitigation measures that follow are supported by recommendations from other studies on operating UASs in the NAS. The specific risk reduction efforts discussed address probability and exposure, and include operating restrictions, procedural separation, and use of technological solutions to compensate for deficiencies in the ability to see and avoid.

**Compensation** includes the use of technological solutions to “compensate” for the lack of ability to see and avoid. These include use of on board sensors (video and IR), ground based radar, and ground observers. The UAS will not fly unless two independent video sources are functioning. Procedures are in place to slew sensors to search in response to traffic advisories. Predator has ability to use sensors to detect traffic. Robust compensation includes codifying use of sensors during mission segments or phases of flight.

**Risk Reduction** options include combinations of operating restrictions, procedural separation, and incorporation of specified procedures and training.

**Operating restrictions** limit UAS operations to the restricted airspace and transition corridor. UAS's will operate away from airways and airports, and away from densely populated areas and roadways. These options effectively reduce the exposure of risk to other aircraft, since midair collision risk is proportional to traffic density.

All corridor transits made by UAS traffic to and from Cannon AFB and Melrose range will be made in accordance with FAA special provisions to ensure "see and avoid" criteria are met. On 8 July 2008, AFSOC/A3U in conjunction with AFSOC/SEF conducted a live rehearsal of this procedure using two light fixed-wing aircraft comparable in size and characteristics to the Predator . The rehearsal was conducted during day and night-time conditions using 5 ground observers separated 4 NMs apart (including Cannon AFB tower). The observers were able to successfully maintain visual contact with the simulated UAS and another aircraft that was acting as the conflicting aircraft during transit across the proposed corridor. This rehearsal was considered equally successful during both day and night-time rehearsals and complied with all FAA guidelines governing the use of ground observers (attachment 1).

A survey of radar observed air traffic (IFR and VFR) that crossed through or over the proposed corridor was conducted by Cannon Radar Approach Control (RAPCON) from 17 March 2008 thru 25 July 2008 (attachment 2). The block altitudes proposed for the corridor are 7300' – 8300' MSL (3000' – 4000' AGL). Data from the survey shows 29 aircraft were observed between 7000' – 9000' MSL during the four month survey. Of all the aircraft documented in the survey, only two did not have transponders and these two were primary radar only.

**Procedural separation** includes all the tools available to separate UASs from other traffic. In addition to conducting operations under positive radar and radio contact, this group of tools includes the Air Traffic Control and UAS equipment that must be functional to ensure flight operations are adequately monitored. Additionally, the UAS will be able to execute and comply with instructions. UAS flights are constantly monitored by a dedicated Cannon AFB RAPCON controller from takeoff to entry within R-5104A. Procedural separation also includes subsets of the actions to be taken during lost link scenarios when the UAS will not respond to instructions, but will follow a predetermined and predictable sequence of events. Lost link procedures are specified in the COA applications. Although the Predator will not respond to commands while lost link, it will proceed directly to published lost link orbits within restricted airspace R-5104A/B. Cannon RAPCON will ensure civilian traffic receives necessary traffic advisories.

Additional procedural **risk reduction** actions are available. In situations where risk cannot be eliminated by design, procedural risk reduction can significantly reduce exposure to risk. Many procedures are already institutionalized, but presented for documentation. Procedural mitigation includes USAF aircrew training, evaluation, and operational procedures in Air Force Instruction 11-202 Volumes 1, 2, and 3. Specific MQ-1 Predator guidance is further refined in Air Force Instructions 11-2MQ-1 Volume 2, and 11-2RQ-1 Volumes 1 and 3. Aircrews are trained to high standards and evaluated periodically to ensure compliance with these standards. Additionally, USAF MQ-1 crews follow all USAF aircrew operational procedures.

Missions are scheduled and briefed in accordance with prescribed standard operating procedures. Pre-mission checklist requirements are in place identifying hazard numbers 11-15 in Table 2 prior to launch, effectively preventing them from becoming *in flight hazards*. For example, preflight inspection criteria and system (aircraft and ground control station) diagnostic checks identify malfunctions causing a mission abort or mission change. Command link settings and mission plans are reviewed prior to launch to ensure proper configuration management of flight critical parameters. All display malfunctions must be corrected prior to launch. Software or hardware anomalies in the aircraft or ground station which cannot be rectified will result in a mission abort prior to launch. The self diagnostic capability of the MQ-1 system virtually eliminates the possibility of an aircrew embarking on a mission with a known malfunction.

UAS activity will be announced through the military NOTAM system, published in the Southwest U.S. Airport/Facility Directory, and annotated in advisories noted on the Albuquerque Sectional chart. To ensure operations are completely monitored, Cannon AFB RAPCON will radar control the flights from Cannon AFB to R-5104A. Redundant systems provide 100% radar and communications coverage, as verified through flight checks. In the extremely unlikely event of a total communications failure, the UAS has the added advantage of communications via telephone.

Due to long mission durations and limited airfield options, the effects of adverse weather must be addressed. Weather minimums are specified in AFI 11-2MQ-1 Volume 2. When weather conditions preclude complying with procedures specified above, missions will be aborted or cancelled prior to launch.

Collision risk can be mitigated through active safety programs. An aggressive mid-air Collision Avoidance (MACA) program reduces risk by providing accurate information to the civilian flying community on the hazards particular to their location. The Cannon MACA program includes procedures to achieve personal contact with owners of gliders and balloons, as well as schools and rental facilities, to ensure local aviators are informed of potential UAS operations.

These risk mitigation measures will not *eliminate* the potential for a midair collision. As per the risk assessment guidance in FAAO 8040 and AFMAN 90-902, assessments may be qualitative as well as quantitative. Research data suggests that the ambient level of risk of a midair collision is on the order of $10^{-7}$ and this is the currently experienced rate of midair collisions in general aviation. Actual traffic counts and Predator sortie numbers within the area between Melrose R-5104A and Cannon AFB Class D along with conservative assumptions used in the research data suggest the unmitigated risk of a midair collision between a Predator and a civilian aircraft is much lower. The combination of methods including mission planning, operating restrictions, procedural separation (including lost link scenarios and procedures), technological compensation, and procedural mitigation measures drive residual risk of collision of a Predator with a civilian aircraft to an even lower level, well within the “extremely remote” classification. The potential loss of an aircraft, UAS, or fatality cannot be assessed at a level less than catastrophic. However, mitigation methods are available to target the likelihood of occurrence, and if applied together will result in a probability of "unlikely." Based on existing criteria, the identified mitigation measures can reasonably be expected to reduce the overall risk to a level of ***Medium***. Implementing these mitigation measures together will ensure the key risks have been identified and mitigated to an acceptable level.

### Selection of Controls and Mitigations

**ACTIONS FOR STEP 4—MAKE CONTROL DECISION**

| **ACTION 1:<br>SELECT RISK CONTROLS** | → | **ACTION 2:<br>MAKE RISK DECISION** |
|---|---|---|

Control decisions involve two major dimensions: the selection of the risk controls and the decision whether or not to accept the residual risk after applying all practical risk controls. This assessment identified a potential risk of midair collision between an Unmanned Aerial Aircraft and another aircraft based on previous studies and mathematical models. The assessment also concluded that the combination of population density, distance from jet routes, victor routes, and local flyways and neighboring restricted areas drives the localized risk for a potential midair collision to a level well below $10^{-7}$ consistent with an acceptable level of safety in both the FAA System Safety Handbook and Mil Std 882. The *unmitigated* risk equates to a level of "High" IAW the AFSOC risk assessment matrix. This level of risk is commonly experienced in daily Air Force operations and is appropriately accepted at the Operations Group Command level. The assessment identified several risk mitigation tools already in use, as well as some to be reviewed for future use. These mitigation measures drive residual risk to a level of "Medium," which is an appropriate level of risk to be accepted at the Squadron Command level. Based on the information presented, the decision maker has the following options:

1. Accept residual risk associated with flying in the proposed corridor.

2. Reject the residual risk and discontinue Predator operations in other than the Class D airspace overlying Cannon AFB.

In conjunction with either option, implementation of the following compensation and risk reduction measures should be documented.

**Compensation:**

1. Continue use of on board sensors, ground based radar, and ground observers.

2. Continue current procedures to slew sensors to search in response to traffic advisories.

3. Continue to ensure Cannon RAPCON controllers have communications with all observed radar traffic, Primary and Secondary, within a 20 NM box prior to releasing the UA into the corridor.

4. Continue to use the UA IR sensor to verify no traffic in the corridor prior to entering the corridor.

5. Continue to use ground observers to verify no observed traffic within the corridor prior to releasing the UA into the corridor.

**Risk Reduction:** (operating restrictions, procedural separation, procedures and training)

1. Continue to limit UAS operations to restricted airspace, Class A airspace, Class D, and in accordance with proposed corridor operations with specific routes and altitudes within areas of verified radio and radar coverage, away from airways and airports, and away from densely populated areas.

2. Continue to use all tools available to procedurally separate UASs from other traffic.

3. Continue to monitor all UAS flights with a dedicated Cannon RAPCON controller.

4. Continue to follow lost link procedures as specified in the COA applications, to include proceeding directly to published lost link orbits within restricted airspace. If the Predator loses link while inside the corridor, Cannon AFB Radar controllers will ensure any potential conflicting traffic receives traffic advisories.

5. Continue to follow procedures specified in Air Force Instruction 11-202 Volumes 1, 2, 3, Air Force Instructions 11-2MQ-1 Volume 2, and 11-2RQ-1 Volumes 1, and 3.

6. Continue to announce UAS activity through the military NOTAM system, Southwest U.S. Airport/Facility Directory, and advisories on the Albuquerque Sectional chart.

7. Restrict UAS flights to Class A airspace, Restricted Airspace, Class D airspace, or airspace within the proposed corridor.

8. Continue the Midair Collision Avoidance (MACA) program efforts in place to achieve personal contact with glider and balloon owners in the local area.

9. Continue to operate at IFR altitudes within the corridor (8000’ MSL to R-5104A; 7000’ MSL from R-5104A to Cannon AFB when feasible.

### Implementation of Controls and Mitigations

**ACTIONS FOR STEP 5—IMPLEMENT RISK CONTROLS**

**ACTION 1: MAKE IMPLEMENTATION CLEAR** → **ACTION 2: ESTABLISH ACCOUNTABILITY** → **ACTION 3: PROVIDE SUPPORT**

Once risk control decisions are made, assets must be made available to implement the specific controls. Part of implementing control measures is informing the personnel of the risk management process results and subsequent decisions. Documentation of the risk management process facilitates risk communication and the rational processes behind risk management decisions. In this case, many of the recommended mitigation actions have already been implemented; therefore, this section serves primarily to document actions taken and provides a reference for further assessments.

### Supervision and Review of Controls and Mitigations

**ACTIONS FOR STEP 6—SUPERVISE AND REVIEW**

**ACTION 1: SUPERVISE** → **ACTION 2: REVIEW** → **ACTION 3: FEEDBACK**

The sixth step of ORM, Supervise and Review, involves determination of the effectiveness of risk controls throughout the operation. This step involves three aspects: monitoring the effectiveness of risk controls, determining the need for further assessment of either all or a portion of the operation, and capturing lessons-learned, both positive and negative, so they may be a part of future activities of the same or similar type.

Predator operations should continue to be monitored to ensure the selected controls are effective and remain in place. Tracking mishap rates, reviewing mishap reports, and monitoring implementation of mishap recommendations will aid in assessing program health. Continued leadership emphasis will help ensure hazards are identified and reported through appropriate processes, including documentation through High Accident Potential (HAP) and Hazardous Air Traffic Reports (HATRs). Changes in operations requiring further assessment must be identified and addressed. New hazards affecting Predator operations should be assessed to determine whether they will affect the conclusions of this assessment. Anytime personnel, equipment, or mission tasking changes or new operations are anticipated in an environment not included in the initial risk analysis, the risks and control measures should be re-evaluated.

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