# National Transportation Safety Board

Washington, D.C. 20594

## Safety Recommendation

**Date:** October 24, 2007

**In reply refer to:** A-07-65 through -69

Honorable Robert A. Sturgell
Acting Administrator
Federal Aviation Administration
Washington, D.C. 20591

On April 25, 2006, about 0350 mountain standard time,[1] an unmanned aircraft (UA) manufactured by General Atomics Aeronautical Systems, Inc. (GA-ASI), crashed approximately 10 nautical miles northwest of Nogales International Airport, Nogales, Arizona, within 100 yards of a house that was located in a sparsely populated residential area. There were no injuries to persons on the ground; the UA sustained substantial damage. The UA was being piloted via data link from a ground control station (GCS) located at the Libby Army Airfield (FHU), Sierra Vista, Arizona. The public-use flight originated from FHU and was performing U.S. border surveillance in night visual meteorological conditions. An instrument flight rules (IFR) flight plan had been filed and activated for the flight.

The accident UA was an unregistered Predator B aircraft owned by the U.S. Customs and Border Protection (CBP), under the Department of Homeland Security. GA-ASI was operating the unmanned aircraft system (UAS)[2] under a contract with the CBP. On March 31, 2006, the Federal Aviation Administration (FAA) issued an authorization for the CBP to operate the UA in the National Airspace System (NAS).

According to GA-ASI, the Predator B is powered by a turboprop engine and has redundant, fault-tolerant avionics as well as the capability to be remotely piloted or fully autonomous. The wingspan of the Predator B is 66 feet, with a maximum weight of 10,000 pounds, maximum altitude ceiling of 50,000 feet, and a flight endurance in excess of 30 hours. The Predator B has the ability to fly more than 220 knots. The UAS was designed as a long-endurance, high-altitude UA for use as a multi-mission system by a variety of customers.

The FAA authorized, via a certificate of authorization (COA),[3] daily operations of the Predator B UAS. A temporary flight restriction (TFR) identified in Flight Data Center Notice to

[1] All times referenced are mountain standard time unless otherwise noted.

[2] The UAS includes the UA, a GCS, and related communications and control elements.

[3] A COA is an authorization issued by the FAA's Air Traffic Organization in response to an Application for Certificate of Waiver or Authorization (FAA Form 7711-2) for a proposed aviation-related activity, such as UA

Airmen (FDC NOTAM) 6/4277, effective March 30, 2006, stated that UA flights may be conducted from 0000 to 1500 coordinated universal time at 15,000 feet mean sea level (msl), which is within the 14,000 to 16,000 feet msl (inclusive) airspace specifically identified in the FDC NOTAM.

The National Transportation Safety Board determined that the probable cause of the accident was the pilot's failure to use checklist procedures when switching operational control from pilot payload operator (PPO)-1 to PPO-2, which resulted in the fuel valve inadvertently being shut off and the subsequent total loss of engine power, and lack of a flight instructor in the GCS, as required by the CBP's approval to allow the pilot to fly the Predator B. Factors associated with the accident were repeated and unresolved console lockups, inadequate maintenance procedures performed by the manufacturer, and the operator's inadequate surveillance of the UAS program.

Based on findings from the Safety Board's investigation of the April 25, 2006, accident, the Board is concerned that deficiencies exist in various aspects of air traffic control (ATC) and air traffic management of UASs in the NAS. The Board has issued 22 safety recommendations to mitigate existing safety risks associated with UAS operations, 5 of which are addressed to the FAA. Information supporting these five recommendations is discussed below.

**Lost Transponder**

The GCS at FHU, from which the accident flight was controlled, contains two nearly identical control consoles: PPO-1 and PPO-2. During a routine CBP mission like the accident flight, the pilot controls the UA from the PPO-1 console, and a payload operator (a U.S. Border Patrol agent) controls a camera mounted on the UA from the PPO-2 console. Operational control of the UA can be transferred from PPO-1 to PPO-2 in the event of a malfunction of PPO-1. The pilot[4] stated in a postaccident interview that, during the accident flight, the console at PPO-1 "locked up," which prompted him to switch control of the UA to PPO-2, as allowed by the system design.

The Safety Board's investigation revealed that, after the console lockup and transfer of control to PPO-2, the engine shut down and the UA functionality degraded quickly as it began to operate on battery power. On battery power, the UA automatically shuts down some aircraft systems to conserve electrical power, including the satellite communication system and the transponder.

The transponder is vitally important to ATC because it provides an enhanced electronic signature, an identification code, and altitude information that are presented on the controller's radar display. The enhanced signature is referred to as a secondary radar return. ATC radars also send a signal that is reflected from the aircraft, referred to as a primary radar return. The primary

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operations. After a complete application is submitted, the FAA conducts a comprehensive operational and technical review of the proposed activity. If necessary, the FAA may impose safety or operational related provisions or limitations as part of the approval.

[4] The accident pilot was a GA-ASI employee who held a commercial pilot certificate with single-engine land, multi-engine land, and instrument ratings. In addition, he held a certified flight instructor certificate with single-engine land, multi-engine land, and instrument ratings.

radar return may be weaker than the secondary radar return and may, therefore, not appear on ATC radar displays. Without an operational transponder, the secondary radar return, identification, and altitude information are not available to ATC. Thus, when the transponder stopped working about 0333, ATC lost secondary radar contact with the UA and was no longer provided altitude information. About 0339, ATC lost primary radar contact with the UA[5] and could no longer provide separation from other aircraft as the UA descended below the TFR-protected airspace.

About 0340, the UA pilot advised the Albuquerque, New Mexico, Air Route Traffic Control Center (ARTCC) that the data link signal that allowed the GCS to control the UA was lost; this is referred to as "lost link." In accordance with FAA-approved procedures, in the event of a lost data link between the GCS and the UA, the UA will fly a flightpath known as the lost-link mission profile, which is a predetermined, autonomous flightpath, until the GCS operation can be restored and line-of-sight (LOS) data link transmissions can be reestablished or the UA returns autonomously to its point of origin. If LOS transmissions cannot be reestablished, and an autonomous return to point-of-origin programming fails, the UA will, after fuel exhaustion, crash somewhere along the route. During a lost-link event with an operating transponder, ATC would be able to track the UA, confirm that the UA was proceeding autonomously to predetermined points, continue to provide separation from other aircraft, and, if required, assist with the search for a missing UA. Without the transponder or primary radar returns, ATC was unable to track the aircraft or provide assistance.

An operating transponder on a UA provides critical safety information, such as the UA's position and altitude, to ATC and other aircraft equipped with traffic collision avoidance systems (TCAS). Unlike manned aircraft, the UA does not have a human backup to provide such information in the event of a failed transponder. Therefore, the Safety Board believes that the FAA should require that UA transponders provide beacon code and altitude information to ATC and to aircraft equipped with TCAS at all times while airborne by ensuring that the transponder is powered via the emergency or battery bus.

**Recording of Communications Between UA Pilots and Air Traffic Controllers, Other UA Pilots, and Other Assets**

Aviation safety investigators have long recognized the value of cockpit voice recorders (CVR) and recordings of ATC radio communications to accurately determine the facts of an accident or incident and have used that information to improve the safety of aircraft operations. During the investigation of this UA accident, Safety Board investigators found that routine radio communications between the UA pilot and ATC controllers were recorded by ATC and did provide valuable information. However, after radar contact was lost and the search for the UA ensued, additional communications by the UA pilot with ATC and other assets[6] involved in supporting the UA operation were conducted by telephone. The telephone conversations were not

[5] ATC was receiving intermittent primary radar returns between 0333 and 0339, after which no UA radar returns were visible on the radarscope.

[6] Assets include the Air Marine Operations Center, which is a communications center for the CBP, and the Western Area Defense Sector (WADS). WADS is an Air National Guard unit; its headquarters are located in Washington State. It protects skies in the western United States by detecting, identifying, tracking, and, if necessary, scrambling fighters to intercept unknown or threatening airborne objects.

recorded. The lack of such recordings hampered the investigation because Board investigators could not evaluate the effectiveness of critical communications between the UA pilot, air traffic controllers, and other assets.

Further, the communications between UA pilot(s) and other personnel within the GCS are not recorded. The value of recording conversations between pilots in a cockpit via the CVR is well known. Recorded conversations between a UA pilot at the GCS and other operational support personnel would be of equal value. A CVR or similar technology in the GCS would enable more complete postaccident and postincident evaluation and reconstruction. Therefore, the Safety Board believes that the FAA should require that all conversations, including telephone conversations, between UA pilots and ATC, other UA pilots, and other assets that provide operational support to UAS operations, be recorded and retained in accordance with FAA Orders 7210.3 and 8020.11.

**Recurring Operational Reviews of Nonstandard Operations**

Interviews with the controllers and facility management at the Albuquerque ARTCC indicated a lack of awareness of the UA's lost-link profile. The lost-link profile was defined in the COA granted by the FAA to the CBP. It specified that the UA was to proceed to a predetermined location and hold until the link was reestablished. ATC personnel indicated that previous UA lost-link occurrences resulted in the UA autonomously returning to the departure airport; in some of those cases, controllers were not aware that the UA had been recovered at the departure airport until the UA pilot advised them. For the accident flight, the lost-link profile did not include a return to the departure airport, nor did it match the profile defined in the FAA COA.

The investigation revealed several ATC deficiencies regarding the lost-link profile. First, the FAA controllers were not familiar with the lost-link profiles as defined in the FAA COA. Second, the controllers were incorrectly assuming that the UA would return to the departure airport as it had done during previous lost-link events. Third, the CBP routinely changed the lost-link profile, and had done so in this case, without updating the COA document issued by the FAA and, more importantly, coordinating the changes with ATC. Fourth, the controllers were not aware of the profile that the UA was actually programmed to fly and, therefore, did not know its route as it maneuvered and descended to the crash site. Thus, ATC controllers were not provided UA operational information that is critical to ATC's responsibility of separating the UA from other known traffic.

A provision of the FAA COA required the UAS pilot to advise ATC of specific information about a UA's anticipated action in the event of a lost link. The UA pilot did not offer such information nor did he declare an emergency. Further, the controller did not solicit information from the pilot when radar contact was lost or when the pilot notified ATC that the lost-link profile was in effect. However, he should have done so, in accordance with FAA Order 7110.65, *Air Traffic Control*, Chapter 10, "Emergencies," which states:

> Consider that an aircraft emergency exists when … there is unexpected loss of radar contact and radio communications with any IFR or VFR [visual flight rules] aircraft. … Start assistance as soon as enough information has been obtained upon

which to act. Information requirements will vary, depending on the existing situation. Minimum required information for in-flight emergencies is:

1. Aircraft identification and type.
2. Nature of the emergency.
3. Pilot's desires.

After initiating action, obtain the following items or any other pertinent information from the pilot or aircraft operator, as necessary:

1. Aircraft altitude.
2. Fuel remaining in time.
3. Pilot reported weather.
4. Pilot capability for IFR flight.
5. Time and place of last known position.
6. Heading since last known position.
7. Airspeed.
8. Navigation equipment capability.
9. NAVAID [navigation aid] signals received.
10. Visible landmarks.
11. Aircraft color.
12. Number of people on board.
13. Point of departure and destination.
14. Emergency equipment on board.

The air traffic controller also could have declared an emergency once he knew that the aircraft was in distress and no longer under the UA pilot's control. Had an emergency been declared, controllers in adjacent facilities as well as pilots operating in the area would have been alerted to a missing aircraft and would have applied additional vigilance to assist in locating it. While the controller stated that he considered this an emergency, he had never declared an emergency as long as he had been a controller. He left that up to his supervisor. His supervisor expected the UA to return autonomously to the departure airport and, about 45 minutes after the link was lost, expected to hear from the UA pilot that the UA had landed, as had occurred in similar situations in the past. After 45 minutes had transpired, the supervisor did not know how to handle the situation. Monitoring UAs is a new ATC responsibility that presents a new challenge.

During the lost-link descent, the UA did not fly in accordance with any flight track that ATC had become accustomed to or the flight track specified in the FAA COA, nor did the pilot inform ATC of the UA's modified, unpublished lost-link profile. This placed an autonomous UA with a maximum gross weight of 10,000 pounds, a ceiling potential of 50,000 feet msl, potential airspeed of 220 knots, and an overall flight duration capability in excess of 30 hours in the NAS without ATC knowing where it was or where it might end up. Clearly, this created a potential hazard to other users of the NAS and persons and property on the ground.

Given the likelihood of increased UAS operations in the NAS, it is critical that UA operators are familiar with ATC procedures and that ATC be familiar with UAS procedures and related system capabilities with emphasis on how UASs and related systems affect the controllers' ability to provide ATC services. Accordingly, the Safety Board believes that the FAA should require periodic operational reviews between the UAS operations teams and local ATC facilities, with specific emphasis on face-to-face coordination between working-level controllers and UA pilot(s), to clearly define responsibilities and actions required for standard and nonstandard UAS operations. These operational reviews should include, but not be limited to, discussion on lost-link profiles and procedures, the potential for unique emergency situations and methods to mitigate them, platform-specific aircraft characteristics, and airspace management procedures.

**Standardized Aircraft Accident and Incident Notification and Reporting**

According to FAA Order 8020.16, *Air Traffic Organization, Aircraft Accident and Incident Notification, Investigation and Reporting*, Chapter 3, Section 65:

> Air traffic facilities must report all known or suspected accidents. The Washington Operations Center must be notified within 2 hours of the original accident report. An example of a suspected accident is the simultaneous unexplained loss of radio communications and radar contact with an aircraft.

Aircraft accident notification is accomplished using FAA Form 8020-3, "Report of Aircraft Accident."

In accordance with FAA Order 7110.65, *Air Traffic Control*, Chapter 10, "Emergencies," paragraph 10-3-1, Overdue Aircraft, ATC should:

> Consider an aircraft to be overdue, initiate the procedures stated in this section and issue an ALNOT[7] [alert notice] when neither communications nor radar contact can be established and 30 minutes have passed since its ETA [estimated time of arrival] over a specified or compulsory reporting point or at a clearance limit in your [the controller's] area, its clearance void time.

ATC did not issue an ALNOT for this accident even though the UA's location was unknown to the controllers responsible for the airspace for nearly 3 hours.

In a July 11, 2006, memo, the manager at the ARTCC stated that the "Albuquerque ARTCC did not complete FAA Form 8020-3 in conjunction with the crash of this Unmanned Aerial Vehicle. Albuquerque ARTCC did not believe this event qualified as an aircraft accident until being notified that this was to be considered a formal accident package." The ARTCC manager further explained that he did not think this flight qualified as an aircraft accident because, as with all UASs, no one boarded the aircraft.

According to Annex 13 to the Convention on International Civil Aviation (ICAO), *Aircraft Accident and Incident Investigation*, Chapter 1, "Definitions," an aircraft accident is "an occurrence associated with the operation of an aircraft which takes place between the time any

[7] An ALNOT is a request from a flight service station or an ARTCC for an extensive communication search for overdue, unreported, or missing aircraft.

person boards the aircraft with the intention of flight until such time as all such persons have disembarked." The Safety Board's rules at 49 *Code of Federal Regulations* (CFR) 830.2, "Definitions," similarly define an aircraft accident as "an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage."

The existence of UASs in the NAS clearly was not contemplated when these definitions of "accident" were developed. The definitions must, therefore, be updated and formal guidance for handling UAS accidents must be developed. Efforts are ongoing to address the definition of aircraft accident in ICAO Annex 13 and 49 CFR 830.2. However, the Safety Board believes that the FAA should require that established procedures for handling piloted aircraft emergencies be applied to UASs.

**Tracking and Analyzing Unmanned Aircraft Incidents and Events that Affect Safety**

UAS operation in the NAS is an evolving activity. The FAA informed Safety Board staff that public-use UAS operations have more than doubled over the past year. All public-use aircraft operations (both manned and unmanned) are exempt from certain aviation safety regulations, and, therefore, operators supervise their own flight operations without oversight from the FAA.[8] For example, Federal aviation regulations pertaining to flight crew training and licensing, aircraft certification, and continuing airworthiness (maintenance) are not applicable to public operations. As a result, the CBP was solely responsible for overseeing the safety of its Predator B operation.

The FAA COA included a set of requirements under which the CBP should operate its Predator B UAS. Many of these requirements, such as requiring the aircraft to be equipped with a transponder and restricting flight over populated or congested areas, were aimed at controlling the risk of a midair collision with other users in the NAS or of injury or damage to persons or property on the ground. These requirements, combined with existing FAA ATC procedures, policies, and requirements for air traffic management of manned aircraft, provide additional controls to ensure the safety of the NAS during UAS operations. Ensuring that all of these safety controls are being properly executed and effectively control the risks from the hazards of UAS operation is fundamental to an effective safety management system[9] and is critical in preventing future accidents.

In manned aircraft operations, tracking and analyzing operational failures and malfunctions of aircraft or ground systems has provided valuable insight into and has improved the effectiveness of both design and operational safety controls; it also has aided in root-cause investigations. For example, the FAA and Safety Board investigators frequently use service difficulty reports to evaluate the frequency and actual effects of safety-related equipment failures. Likewise, safety feedback systems, such as aviation safety action programs, provide objective data used to evaluate the effectiveness of operational safety controls, such as training, procedures, and checklists.

[8] The FAA has limited oversight authority over public-use aircraft operations.

[9] See FAA Advisory Circular 120-92, "Introduction to Safety Management Systems for Air Operators."

At the time of this accident, the FAA did not require the CBP to provide reports of or analyze significant operational safety incidents or malfunctions involving Predator B operations. For example, the first link in the chain of events that led to the accident involved a fault in the GCS component of the UAS, which caused the primary control console to lock up. The Safety Board's review of computer logs in the GCS showed a similar lockup had occurred on April 19, 2006, just 6 days before the accident. Additionally, the fault occurred twice on the day of the accident, before takeoff. Another log of lockups was kept at the technician's station in the GCS. This log showed 9 lockups in a 3-month period before the accident.

These GCS lockups are a potential safety concern because they can result in the momentary loss of control of a UA. However, despite the repeated lockup events noted by Safety Board investigators, the CBP continued to fly the UA without identifying the root cause of the lockups and/or analyzing the impact these events could have on the CBP's ability to keep the UA within the approved operating area of the NAS. Further, while ATC safety controls, such as the UA flying published flight profiles allowing for separation from other aircraft, could aid in mitigating risk of an uncontrolled TFR breach, these controls were not implemented in accordance with the FAA COA in this accident sequence. The Safety Board concludes that data tracking and analysis programs could help identify deficiencies in the safety control plans or their implementation for UASs before they lead to an accident.

The FAA indicated to Safety Board staff that it now requires UAS operators to report irregularities, such as the repeated control-console lockups. However, the Board is concerned that the FAA will not analyze this type of data when evaluating the effectiveness of safety controls for public UAS operations, such as operating requirements, procedures, and training, because of a flight's public-use status. Further, there may be many public-use operators of a specific model of UAS, which increases the need for a centralized repository of safety information related to the operation of that particular UAS. The Safety Board concludes that periodic review and analysis of these data by the UA operator, whether public or civilian, with oversight by the FAA, is critical to ensure that the safety controls put in place for UAS operations work as intended and are being properly implemented to mitigate risk to the NAS and to ensure that UA operators and ATC take timely corrective action when the controls are shown to be ineffective.

The lessons learned and opportunity for accident prevention through the use of an effective events-monitoring system for all UAS operations are critical, given the increase in UAS operations in the NAS and the future likelihood of their direct integration with manned aircraft throughout the NAS. In particular, absence of a proven track record for UAS operations in the NAS reinforces the need to collect operational data to verify the adequacy and effectiveness of planned safety controls. The Safety Board concludes that now is the time, while operations are conducted only in sparsely populated locations, to build critical knowledge on how to safely operate UASs in the NAS; thus, a program for monitoring safety assurance is imperative to achieve that end. Therefore, the Safety Board believes that the FAA should require that all UAS operators report to the FAA, in writing within 30 days of occurrence, all incidents and malfunctions that affect safety; require that operators are analyzing these data in an effort to improve safety; and evaluate these data to determine whether programs and procedures, including those under ATC, remain effective in mitigating safety risks.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Require that unmanned aircraft transponders provide beacon code and altitude information to air traffic control and to aircraft equipped with traffic collision avoidance systems at all times while airborne by ensuring that the transponder is powered via the emergency or battery bus. (A-07-65)
>
> Require that all conversations, including telephone conversations, between unmanned aircraft (UA) pilots and air traffic control, other UA pilots, and other assets that provide operational support to unmanned aircraft system operations, be recorded and retained in accordance with Federal Aviation Administration Orders 7210.3 and 8020.11. (A-07-66)
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> Require periodic operational reviews between the unmanned aircraft system (UAS) operations teams and local air traffic control facilities, with specific emphasis on face-to-face coordination between working-level controllers and unmanned aircraft pilot(s), to clearly define responsibilities and actions required for standard and nonstandard UAS operations. These operational reviews should include, but not be limited to, discussion on lost-link profiles and procedures, the potential for unique emergency situations and methods to mitigate them, platform-specific aircraft characteristics, and airspace management procedures. (A-07-67)
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> Require that established procedures for handling piloted aircraft emergencies be applied to unmanned aircraft systems. (A-07-68)
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> Require that all unmanned aircraft system operators report to the Federal Aviation Administration, in writing within 30 days of occurrence, all incidents and malfunctions that affect safety; require that operators are analyzing these data in an effort to improve safety; and evaluate these data to determine whether programs and procedures, including those under air traffic control, remain effective in mitigating safety risks. (A-07-69)

The Safety Board also issued 17 recommendations to U.S. Customs and Border Protection. In your response to this letter, please refer to Safety Recommendation A-07-65 through -69.

Chairman ROSENKER, Vice Chairman SUMWALT, and Members HERSMAN, HIGGINS, and CHEALANDER concurred with these recommendations.

[*Original Signed*]

By: Mark V. Rosenker
Chairman