# Special Investigation Report on the Safety of Agricultural Aircraft Operations


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## Special Investigation Report on the Safety of Agricultural Aircraft Operations

National Transportation Safety Board

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**Abstract:** This special investigation report describes the results of a National Transportation Safety Board (NTSB) review of 78 accidents that occurred during calendar year 2013 and involved some aspect of agricultural (ag) operations, pilot training, or other crop protection activities. The report identifies the following recurring safety issues: lack of ag operations-specific fatigue management guidance, lack of ag operations-specific risk management guidance, inadequate aircraft maintenance, and lack of guidance for pilot knowledge and skills tests. Safety recommendations to the Federal Aviation Administration and to the National Agricultural Aviation Research & Education Foundation are included. The Appendix at the end of the report contains a full listing by NTSB case number of the accidents reviewed for the special investigation.

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# Acronyms and Abbreviations

| | |
|---|---|
| **AC** | advisory circular |
| **AWEA** | American Wind Energy Association |
| **CFR** | *Code of Federal Regulations* |
| **DOD** | Department of Defense |
| **DOI** | Department of the Interior |
| **FAA** | Federal Aviation Administration |
| **FAASTeam** | FAA Safety Team |
| **GA** | general aviation |
| **MET** | meteorological evaluation tower |
| **NAAA** | National Agricultural Aviation Association |
| **NAAREF** | National Agricultural Aviation Research & Education Foundation |
| **NTSB** | National Transportation Safety Board |
| **PAASS** | Professional Aerial Applicators' Support System |
| **SAFO** | safety alert for operators |
| **SB** | service bulletin |
| **SIL** | service information letter |
| **TBO** | time between overhaul |
| **USDA** | US Department of Agriculture |

# 1. Introduction

Agricultural aircraft operations (commonly referred to as "ag operations") involve the use of airplanes and helicopters for dispensing activities—including the aerial application of fertilizers, seeds, and crop protection products such as those used to control pests, weeds, and harmful fungi—that directly affect agriculture, horticulture, or forest preservation.[1] Ag operations are conducted under the provisions of 14 *Code of Federal Regulations* (CFR) Part 137, which provides operation-specific requirements and certain exceptions from the 14 CFR Part 91 operating rules.[2] A review of historical accident data and the findings of several ag aircraft accident investigations prompted the National Transportation Safety Board (NTSB) to initiate this special investigation to identify safety issues in this unique general aviation (GA) sector and to suggest action to address these issues.[3] According to the National Agricultural Aviation Association (NAAA), an industry group representing about 1,800 members nationwide, about 1,350 aerial application businesses employ about 2,700 ag pilots in the United States (NAAA 2012, 28).

The mission priorities of ag operations present pilots with unique hazards, challenges, and constraints, some of which cannot be completely eliminated. For example, ag pilots must maneuver their aircraft at very low altitude over terrain and must therefore accept an elevated risk of terrain and obstacle collisions, as well as having limited time to safely respond to an aircraft mechanical anomaly or recover from an inadvertent aerodynamic stall. Also, as a typically single-pilot operation, ag flying places high demands on pilots' attention. In addition to flying their aircraft, ag pilots must operate their dispensing equipment and adjust their swath runs (often while monitoring in-cockpit resources such as GPS-aided precision aerial swathing equipment) to manage product drift and ensure quality coverage. They also must monitor the outside environment for a variety of considerations, such as weather phenomena (that can affect visibility or product drift), work area boundaries, obstacles, and areas to be avoided due to populations, noise abatement, livestock, or other safety considerations. Finally, seasonal crop schedules, weather conditions, the potential for crop damage if a job is not completed, competition for contracts, and other factors can influence pilots' or operators' scheduling practices, creating demanding work schedules that pressure pilots to complete work within a

[1] Specifically, 14 *Code of Federal Regulations* (CFR) 137.3 defines an agricultural aircraft operation as "the operation of an aircraft for the purpose of (1) dispensing any economic poison, (2) dispensing any other substance intended for plant nourishment, soil treatment, propagation of plant life, or pest control, or (3) engaging in dispensing activities directly affecting agriculture, horticulture, or forest preservation, but not including the dispensing of live insects." The same regulation defines an economic poison as "(1) any substance…intended for preventing, destroying, repelling, or mitigating any insect, rodents, nematodes, fungi, weeds, and other forms of plant or animal life or viruses…[that are declared by the Secretary of Agriculture to be a pest], and (2) any substance…intended for use as a plant regulator, defoliant, or desiccant."

[2] Although the Federal Aviation Administration (FAA) provides oversight of ag aircraft operations, because of the different types of products that aircraft can carry, ag operations are also subject to other regulatory authority, including that of the Environmental Protection Agency, other federal agencies, and individual state, tribal, territorial, and local agencies (O'Connor-Marer 2011, 9-10). Requirements for aerial pesticide applicator certification vary by state, and some states specify pilot training and experience criteria beyond what are required by the FAA.

[3] GA encompasses all operations not conducted under 14 CFR Parts 121, 135, or 129 and includes a wide variety of operations and aircraft, from powered parachutes and light sport aircraft to turboprops and jets. GA sectors include personal flying, flight instruction, aerial application, public aircraft operations, and a variety of other operations categorized by the purpose of the flight.

certain period of time. (See figure 1.) These factors, separately or variously combined, can contribute to pilot fatigue and other performance-degrading effects.

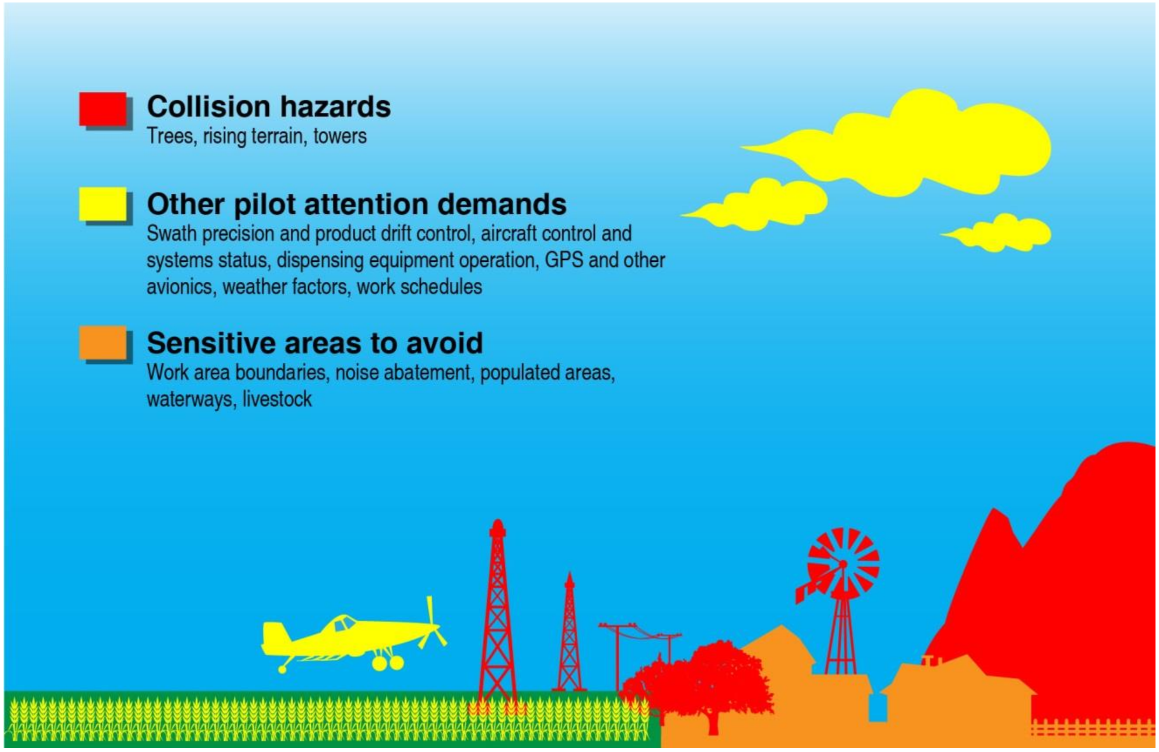


**Figure 1.** Hazards, constraints, and pilot attention demands common to ag operations.

The unique hazards and risks associated with ag operations are reflected in historical accident data. From 2001 through 2010, 802 ag operations accidents occurred, including 81 that were fatal (NTSB 2012, 48-54).[4] In recent years, ag operations have ranked sixth or seventh among GA sectors in terms of hours flown (FAA 2012). However, in terms of total number of annual accidents, the ag operations sector has ranked third, and its 10-year average total accident rate is above the 10-year average total GA accident rate (NTSB 2012, 54). Data for calendar year 2010 show that engine system or component failures accounted for the most common defining event for ag operations accidents (28 accidents), followed closely by collision events (27 accidents), then accidents involving a pilot's loss of aircraft control, both in flight (6 accidents) and on the ground (6 accidents) (NTSB 2012, 48-54). Compared to the pilots in other GA sectors, ag operations pilots who were involved in accidents tended to be highly experienced. For 2010, the average total flight time for an ag pilot involved in an accident was about 10,400 hours with about 2,900 hours in aircraft type (NTSB 2012, 54).

This special investigation focused on accidents that occurred during calendar year 2013. Special emphasis was placed on accidents occurring between January and October 2013, capturing the peak ag season and targeting those accidents for additional data collection in such areas as pilot work and sleep schedules, pilot training and experience, and aircraft maintenance.

[4] As of the completion of this special investigation, calendar year 2010 is the most recent year for which the NTSB had published a review. For ag operations accidents, the data included only flights conducted under Part 137.

In an effort to collect as much relevant data as possible, the focus of this special investigation extended beyond aerial application flights conducted under Part 137. Accidents involving ag operators' maintenance and repositioning flights, ag pilot training, and other crop protection activities were also considered.[5]

During calendar year 2013, the NTSB investigated 78 aircraft accidents that involved some aspect of ag operations, ag pilot training, or other crop protection activities; nine of these accidents were fatal and claimed the lives of 10 people.[6] Seventy-four accidents involved Part 137 operators, including 66 accidents that occurred during Part 137 flights and 8 accidents that involved aircraft that the pilots typically operated under Part 137 but were operating under Part 91 at the time of the accident. Other accidents included a Part 91 training flight for a pilot who wished to become an ag pilot (neither the student nor the instructor had any Part 137 experience), a public aircraft[7] flight involving seed-dispersal operations, and two Part 91 crop protection flights (cherry-tree drying and frost prevention) performed by pilots who did not have Part 137 experience.

A review of the accidents that occurred in 2013 revealed trends consistent with historical accident data for the Part 137 GA sector: the top three defining events were in-flight collision with an obstacle, loss of aircraft control, and system or component failure (both powerplant and nonpowerplant). Because it is consistently one of the most common (and often fatal) accident types, obstacle collision remains a top industry concern. The NAAA reports that, according to its 2012 survey, ag operators and pilots considered power lines, communication towers, and meteorological evaluation towers (MET) as the most critical hazards to their operations (NAAA 2012) (the hazards associated with METs have been the subject of previous NTSB safety action, which is described in section 6 of this report).[8,9] Sixteen ag-related accidents in 2013 (13 of which occurred during Part 137 flights) involved an in-flight collision with an obstacle (including power lines, guy wires, trees, and a MET), and three of these accidents (two of which occurred during Part 137 flights) were fatal. In some of the accidents involving obstacle collisions, the pilot was not previously aware of the obstacle and did not see it in time to avoid

5 Because historical accident data for ag operations typically include only Part 137 flights, all discussions of the 2013 accident totals throughout this report also specify how many flights in various accident categories were conducted under Part 137.

6 Five of the fatalities occurred during Part 137 aerial application flights, two occurred during a Part 91 training flight, and one occurred during a Part 91 frost prevention flight. One person died during an accident involving a public aircraft conducting a seed-dispersal flight, and one runway worker was fatally injured by an ag operator's airplane during a Part 91 repositioning flight. See the Appendix for a full listing of the accidents by NTSB case number.

7 Public aircraft, as defined in 49 *United States Code* 40102(a)(37), are aircraft operated by certain government entities for noncommercial purposes. Public aircraft are not subject to some of the regulatory requirements applicable to civil aircraft, and their operations generally include law enforcement, low-level observation, aerial application, firefighting, search and rescue, biological or geological resource management, and aeronautical research.

8 According to the NAAA, 508 operators and 324 pilots responded to the survey, a summary of which can be accessed from the NAAA's website at www.agaviation.org. The website also describes the NAAA's concerns about real-time kinematic towers, which are used by farming machinery equipped with precision navigation capabilities, such as hands-free assisted steering.

9 METs are temporary structures used to measure wind speed and direction during the development of wind energy conversion facilities. METs are made from galvanized tubing (or other galvanized structure) with a diameter of 6 to 8 inches and are secured with guy wires.

the collision because it was not visually conspicuous. In other cases, the pilot knew about the obstacle, having seen it during a previous pass, a survey flight, or while on a collision course with it, but misjudged the aircraft's distance from it. Other accidents involved terrain collisions unrelated to obstacles, including four accidents in which the pilots were distracted and allowed their aircraft to descend unnoticed.[10]

While accident data typically categorize accident types based on a defining event (such as obstacle collision, loss of aircraft control, or component failure), the NTSB's accident investigations reveal that a variety of accident causes, factors, and other safety concerns are associated with each type. For example, pilot fatigue was found to have played a role in three of the collision accidents and two loss-of-control accidents in 2013. Inadequate risk management practices or inadequate pilot skills or training issues can often be associated with collision or control-loss accidents, and aircraft component failures often result from improper maintenance. This special investigation's review of the completed aircraft accident reports and collected data identified the following safety issues:

- Lack of ag operations-specific fatigue management guidance
- Lack of ag operations-specific risk management guidance
- Inadequate aircraft maintenance
- Lack of guidance for pilot knowledge and skills tests

As a result of this special investigation, the NTSB has issued four new safety recommendations to the FAA and four to the National Agricultural Aviation Research & Education Foundation (NAAREF) to address these safety concerns.[11]

[10] The reports for these accidents, WPR14CA003, CEN13LA265, CEN13LA447, and CEN13LA442, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

[11] The NAAREF is a nonprofit organization with a Board appointed by the National Agricultural Aviation Association's board of directors.

# 2. Fatigue

Pilots in all sectors of aviation are vulnerable to the performance degrading effects of fatigue. Fatigue can result from a number of factors but typically is associated with obtaining inadequate restorative sleep (due to restricted sleep opportunities), not appropriately using available sleep opportunities, or other factors such as medical conditions that can affect the quantity and quality of sleep. Extended wakefulness and circadian disruption (which occurs when a pilot works during a time when he or she otherwise would be asleep) also cause fatigue. Demanding and sustained work periods or activities can lead to performance degradation, even if the pilot received adequate sleep before starting work.

Because of the seasonal nature of crop needs, many ag operators experience a busy season characterized by long work days and work weeks. Some applications may be time-sensitive based on an immediate need to mitigate certain harmful insects or moisture or to address other crop concerns. Therefore, if the job is not done promptly, crop losses can result. Ag operators take seriously their role in crop protection and, like any commercial entity, face pressures to gain and retain business by completing work to the customers' satisfaction.

A review of statements from pilots and operators involved in all types of ag operations accidents in 2013 revealed that many typically worked from sunup to sundown and that many work days exceeded 12 hours. One pilot reported that, during the busy season (which is the summer for most operators), work days would be as long as 16 hours with 10 to 11 hours of flying per day. Another pilot reported that the night shift was from 5 p.m. to midnight with some shifts extending until 2 a.m. Several pilots noted that the length of their work days and work weeks was weather-dependent. Factors such as fog, low clouds, and rain can limit flying on one day, which can increase the amount of work that must be completed on days when the weather is favorable.

Fatigue was cited as a cause or factor in five of the accidents that occurred in 2013, four of which involved Part 137 flights. In one accident, the pilot of a Piper PA-36-300 airplane was conducting a pull-up after a spray pass in a small, tightly confined field, and the airplane collided with a tree. Although the pilot typically slept at least 7 hours per night, his sleep was disturbed several times during the night before the accident. The pilot reported that he regretted his decision to accept the challenging job and that he did so only after multiple requests from the landowner.[12] This pilot noted that the accident could have been prevented "by not attempting to finish a small area to meet perceived customer demand." Thus, in addition to fatigue, perceived external pressures and workload challenges may have been present.

In a second fatigue-related accident, the pilot lost control of an Arrow Falcon Exporters OH-58+ helicopter while maneuvering to avoid power lines during the 15th load of his shift. The accident occurred around midnight, about 14 hours after the pilot's last sleep period, which was a

[12] The report for this accident, CEN13LA464, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

1-hour nap. This pilot was fatigued because he was working at a time when he normally would be asleep and had been awake a relatively long time.[13] (See figure 2.)


**Figure 2.** Wreckage of an Arrow Falcon Exporters OH-58+ helicopter.

A third accident involved a public aircraft operations pilot of a Bell 206B who died after his helicopter collided with a static line located above three sets of tandem power cables. The pilot had conducted multiple seed-dispersal flights throughout the day and the investigation found that he was subject to task- and/or work-related fatigue.[14] A fourth fatigue-related accident involved a pilot who lost control of a Schweizer G-164D during a wake turbulence encounter. The pilot had been awake for 15 hours, having flown 71 application loads during the 12 hours that preceded the accident, and was fatigued due to extended hours of wakefulness and high workload.[15] In a fifth fatigue-related accident, which involved a loss of control of a Weatherly 620B airplane while maneuvering, the pilot reportedly had slept well for about 7 to 8 hours but had flown about 9 hours before the accident. His only known break involved taking 10 to 15 minutes for lunch about 6.5 hours before the accident.[16] (See figure 3.)

[13] The report for this accident, WPR13LA215, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

[14] The report for this accident, WPR13GA128, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

[15] The report for this accident, WPR13LA233, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

[16] The report for this accident, CEN13FA324, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

**Figure 3.** Wreckage of a Weatherly 602B airplane.

Unlike some other civilian and military aviation sectors, no maximum flight time or duty period limitations apply to Part 137 operations. For example, Section 135.267 limits air tour pilots to 8 hours of flight time per consecutive 24-hour period for single-pilot operations. More flight time is permitted as long as the anticipated duty period will not exceed 14 hours and is preceded and followed by rest periods of at least 10 hours. US Army flight regulations allow local commanders flexibility in developing flight time limitations for helicopter pilots, but the regulations recommend that helicopter pilot flight time be limited to 8 hours per 24-hour period.[17] The Army also recognizes that there are additional stresses associated with low-level helicopter flying, and its regulations recommend that the maximum flight times for flight at or below 200 feet above ground level be reduced to 6.15 hours per 24-hour period.

Aside from the time of day and length of duty day considerations, the continuous, repetitive, low-altitude flying associated with ag aircraft operations also can be fatigue-inducing for pilots. A research study on pilot fatigue in a noisy, vibrating helicopter simulator found considerable increases in subjective fatigue after 6 hours of short, repetitive flights. At the end of this period, some helicopter pilots who participated in the study said that they were so fatigued that they did not feel safe to fly a real helicopter. As subjective fatigue increased, study pilots demonstrated increasingly frequent lapses in performance. The study also found that routine, hourly rest breaks outside the cockpit reduced the buildup of fatigue to manageable levels, even when flight periods were extended to 8 hours (Stave 1977).

[17] US Army Regulation 95-1 (1997).

Demanding scheduling practices can also leave pilots susceptible to dehydration, hunger, and other factors that can negatively affect a pilot's concentration, decision-making, and performance. These types of issues have contributed to fatal accidents in other aviation sectors. For example, the pilot of a Bell 206B helicopter and four passengers died when the helicopter collided with mountainous terrain during a Part 91 air tour flight in 2004 (NTSB 2007). The NTSB's investigation found that the operator's scheduling practices likely had an adverse impact on the pilot's decision-making and performance. The pilot did not have any scheduled breaks and ate lunch between tour flights (if at all) while sitting in the helicopter with the rotors turning. The pilot had no access to any shelter or restroom facilities. In addition to these working conditions being conducive to fatigue, the investigation found that they probably discouraged the pilot from consuming food and liquids during the work day to avoid the physiological need for a restroom. This increased the risk of dehydration and other physiological problems, which could have degraded the pilot's performance. At the time of that accident, he had been at the controls of the helicopter for almost 8 hours with the rotors turning, leaving the cockpit only once. Because of similarities in the type of demanding work day, the lessons learned from this air tour accident investigation can be applied to help enhance the safety of ag aircraft operations.

In the absence of maximum flight time or duty period limitations, ag operators and pilots can improve the safety of their flight operations by developing scheduling practices that take into consideration the limitations that apply to commercial and military aviation sectors that involve repetitive flights and low-altitude profiles. For example, ag aircraft pilots and operators can take measures to reduce the duration of on-duty periods by streamlining administrative tasks such as work-order preparation, record-keeping, and preflight so that a pilot's duty day is not unnecessarily extended. Although some FAA guidance and educational materials (including FAA Safety Team [FAASTeam] online courses and posters) address such topics as fatigue countermeasures strategies, aeronautical decision-making for visual flight rules pilots, and personal minimums checklists, there are no detailed FAA guidance materials that address the issues associated with the continuous, repetitive, low-altitude flights specific to ag aircraft operations. The NTSB concludes that guidance for fatigue management is lacking for ag aircraft operations and such guidance could help operators and pilots develop effective strategies to reduce the likelihood of fatigue, dehydration, hunger, and other physiological factors that can negatively affect a pilot's concentration, decision-making, and performance.

The NTSB notes that human performance and aeronautical decision-making training and education are focal areas of the Professional Aerial Applicators' Support System (PAASS), a program established in 1996 by the NAAREF.[18] Both the FAASTeam and PAASS have worked together to develop educational materials and programs, some of which have qualified for FAA Wings Program credit and various state ag departments' continuing education requirements. During its 2012-2013 sessions, the PAASS program was able to reach a large percentage of the estimated ag pilot population.[19] Because the PAASS program development committee possesses

[18] The PAASS program development committee is made up of operators, pilots, government, and industry representatives.

[19] According to the NAAA, 1,994 registered attendees participated in the PAASS program during its 2012-2013 sessions, which run from October through March. If that number represents unique registrants, the program reached about 74 percent of the estimated ag pilot population. However, the NAAA noted a possibility that some attendees may not have registered and that others could have been counted twice if they attended more than one program during the year.

industry knowledge and has demonstrated its ability to work in conjunction with the FAA to develop and widely disseminate training and educational materials to the ag operations community, the NAAREF is an important resource for developing and distributing safety-related guidance materials intended to help prevent accidents. Therefore, the NTSB recommends that the FAA, in conjunction with the NAAREF, develop and distribute ag aircraft operations-specific guidance on fatigue, fatigue management strategies, and scheduling practices to help reduce the likelihood of fatigue, dehydration, hunger, and other physiological factors that can negatively affect a pilot’s concentration, decision-making, and performance. The NTSB also recommends that the NAAREF work with the FAA to develop and distribute this guidance.

# 3. Attention Demands and Risk Management Practices

Pilots rely on multiple sources of information, both inside and outside the cockpit, to maintain aircraft control and navigate safely. Safe pilots must be efficient at directing and redirecting their attention, which is critical in ag operations because the close proximity to obstacles and terrain and the airspeeds at which the aircraft are flown reduce the available time for pilot response. Any lapse in concentration or imprecision in control input can lead to catastrophic consequences. Even highly skilled and experienced ag pilots can experience performance and decision-making degradation for a variety of reasons.

In one wire-collision accident, the pilot of a Texas Helicopter OH-13E/M74 had previously observed the power line but, during his first application pass, experienced what he described as a "momentary lapse," and flew the helicopter through the wires.[20] The pilot had about 5,000 hours total flight time with about 2,500 hours in the accident model helicopter. In this case, the pilot did not adequately monitor the environment and maintain clearance from the wires. However, performance-degrading factors like high attention demands, fatigue, and stress (which can include external or self-induced pressures to get the job done) can affect any pilot. Applying effective risk management practices can alleviate some of these factors to make the flight safer.

## 3.1 Attention Demands

One of the many additional demands for their attention that ag pilots face is managing the spray application while maneuvering their aircraft at low altitude. Ag pilots must always be mindful of, and work within, the constraints specific to the product that they are applying. For example, some pesticides may contain restrictions related to the temperature at which they can be used. Pilots must also consider the height appropriate for the application, prohibitions due to nearby sensitive areas, and requirements for buffer zones (O'Connor-Marer 2011, 22). Improper applications can destroy crops, contaminate soil, lead to pest resistance and resurgence, or adversely affect human health, the environment, and other plant and animal life. Operators can also be subject to substantial fines and penalties.

To conduct effective aerial applications that maximize benefits to the target crop and minimize the potential for misapplication, ag pilots must devote considerable attention to controlling the spray flow, adjusting the location of swath runs and cleanup trim passes, and operating the spraying system equipment. To accomplish these goals while maneuvering the airplane at low altitude, pilots must visually scan external cues (outside the window) to help maintain aircraft control and obstacle avoidance while monitoring a variety of internal (inside the cockpit) resources, including paper or electronic property maps and instruments for spray system, navigation, and aircraft status information.

[20] The report for this accident, WPR13LA429, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

Although onboard equipment types can vary, NAAA industry surveys show that 93% of the operators who responded in 2012 reported that they used GPS as their primary means of swath guidance and that 99% of their aircraft had a GPS system with a mounted light bar.[21,22] A GPS display can also show the pilot the aircraft's location when the spray was turned on or off and can enable the marking of boundaries, obstacles, and other user-defined inputs. (See figure 4.)

**Figure 4.** GPS swath guidance system installed in a two-seat training aircraft.
The swath guidance display is indicated with the blue arrow. The light bar (indicated with the yellow arrow) is mounted outside the cockpit windscreen.

In one of the 2013 accidents involving pilot distraction, the pilot of a Texas Helicopter OH-13H/M74A inadvertently descended the helicopter into the corn crop while spraying a "J"-shaped field. The pilot reported that, after completing the turn toward the small section of the field, he checked the light bar and then "saw corn in the windshield" and the helicopter rolled upside-down.[23] In an accident involving an Air Tractor AT 402B, the pilot was maneuvering the airplane in dark night conditions over a rural area with few ground lights when he focused his attention on a map in an effort to locate the correct field to spray. As he did so, the

[21] A light bar is a component of GPS-aided precision aerial swathing that enables a pilot to visualize the aircraft position in relation to the desired swath course centerline. Lights to the left and right of center represent the aircraft's position relative to the desired swath centerline. The distance represented by each light is typically 2 feet to 6 inches, depending on set user preferences.

[22] A summary of the survey results can be accessed from the NAAA's web site at www.agaviation.org.

[23] The report for this accident, CEN13LA442, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

airplane descended unnoticed and collided with terrain.[24] The pilot reported that the map supplied by the farmer was of poor quality and that he was having difficulty interpreting it.

FAA Advisory Circular (AC) 137-1A, “Certification Process for Agricultural Operators,” contains some guidance related to attention management for ag pilots (FAA 2007). The AC states that pilots should use extreme caution when using GPS swath-marking equipment to prevent diverting attention away from the task of flying the aircraft safely. The AC also cautions pilots about the dangers of fixating on the light bar or adjusting the computer during a swath run and states that looking back at a swath during a swath run can result in an unintentional collision with the ground or obstacles. Attention management, in the form of identifying and recognizing the multiple demands in advance and taking steps to minimize operational distractions, can be incorporated into an ag pilot’s overall risk management plan.

## 3.2 Risk Management

Risk management is a decision-making process by which pilots can systematically identify hazards, assess the degree of risk, and determine the best course of action. Effective risk management involves good decision-making that allows a pilot to identify personal attitudes that are hazardous to safe flying, apply behavioral modification techniques, recognize and cope with stress, and effectively use all resources. Risk management strategies can help pilots apply a systematic process that can help them resist pressures that can adversely affect their decision-making and performance and can help them mitigate other hazards that could adversely affect the safety of flight.

For example, the fatigued pilot in NTSB case number CEN13LA464, who reluctantly accepted a challenging job and later regretted it, may have benefitted from performing a structured risk assessment to help him determine that he was fatigued, that the risks associated with spraying that particular field were too high, and that the job should not be accepted. Similarly, the pilot in case number WPR14CA003, who was distracted by trying to read a poor-quality map in flight, could have mitigated that hazardous in-flight diversion of attention before departure by cross-checking the map with online resources, conducting a ground survey, and/or adding waypoint information into the aircraft navigation systems. Such map-checking could be incorporated into preflight risk management procedures. Also, because maneuvering an aircraft in challenging conditions or while distracted can also lead to aerodynamic stall accidents (which are almost always fatal when they occur at low altitude), stall awareness and avoidance techniques are critical for ag pilots.

Another important element in managing risk in a challenging operational environment is proper preflight planning. Two fuel-exhaustion accidents occurred in 2013 in which improper preflight planning played a role. In one accident, the pilot of an Air Tractor AT-602 airplane had finished spraying a field but was airborne longer than planned because he could not find his intended destination. After circling in the area looking for the airport, the pilot decided to search for an alternative, which he eventually found but aborted the approach after realizing that it had a control tower with which he had no communication. The engine eventually lost power due to

[24] The report for this accident, WPR14CA003, can be searched by accident number from the NTSB’s Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

fuel exhaustion, and the airplane was substantially damaged during the forced landing.[25] In the second accident, the pilot of an Air Tractor AT-301 airplane disregarded low-fuel readings on the airplane's fuel gauges because he believed that the airplane had more fuel than indicated.[26] Other accidents in which improper preflight planning played a role involved a lack of pilot attention to aircraft performance considerations, such as the adverse effects of density altitude, a pilot's decision to land an airplane with a crosswind that exceeded the airplane's capabilities, and a helicopter loaded outside its weight and balance limitations.[27] The risks associated with each of these accidents could have been mitigated with more thorough preflight and in-flight planning practices.

A common preflight planning task in ag operations is conducting a survey flight to determine potential obstacle collision risks. Three pilots involved in collision accidents in 2013 reported that they performed survey flights but did not see the obstacles that the aircraft eventually hit.[28] One of these accidents involved the pilot of a Bell 206B helicopter who reported that he had circled over a field three times looking for obstructions but did not see power lines at the site until they contacted the windscreen. (See figure 5.)

These accidents suggest that aerial surveys alone are insufficient to mitigate the risk of collisions with obstacles that are difficult to see. During the investigation of the Bell 206B helicopter accident, the NTSB investigator-in-charge reviewed the operator's policies and procedures manual and found that it did not specify that potential flight hazards be identified during a required pre-work conference. The operator subsequently amended the manual to indicate that all personnel (the pilot, the tract representative, ground crew, and others) agree on and understand potential flight hazards during the pre-work conference.

**Figure 5.** Wreckage of a Bell 206B that struck power lines (left) and the severed lines (right).

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[25] The report for this accident, CEN13LA293, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

[26] The report for this accident, WPR13LA248, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

[27] The reports for these accidents, CEN13LA371, CEN13LA533, CEN13LA323, and WPR13LA217, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

[28] The reports for these accidents, CEN13LA263, ERA13LA236, and CEN13LA425, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

Other accidents involved collisions with obstacles that were known to the pilot or had characteristics that would make them visibly conspicuous. In some of these accidents, the pilots reported that they saw the obstacle but misjudged the aircraft's distance from it. In other accidents, the pilots saw the obstacle during survey passes but collided with it during a spray pass. These types of accidents show that enhancing obstacle conspicuity, although an important safety improvement, is only part of the solution in reducing collision risks. The habitual use of preflight discussions with persons familiar with the work area and its obstacles, area maps (both paper and electronic) with the obstacle locations marked, ground surveys, and a policy and procedures manual that covers the preflight discussion of potential flight hazards are some methods that can help. To help promote such practices, the NTSB has issued, concurrent with this report, a safety alert, "Preventing Obstacle Collisions in Agricultural Aviation." The safety alert describes some of the collision accidents from 2013 and provides tips for pilots and operators to avoid such accidents.[29]

The FAASTeam offers several online educational resources related to aeronautical decision-making, and the FAA's Risk Management Handbook offers an in-depth discussion of risk management strategies; however, these resources do not address the unique hazards and risks associated with ag operations. For example, the Risk Management Handbook dedicates entire chapters to the topics of identifying hazards and mitigating risks, single-pilot resource management, and automation, but no scenarios specific to ag operations are discussed. Although the FAASTeam has developed and distributes some ag-specific safety tools, including a personal minimums checklist for aerial applicators and a poster offering practical tips for avoiding takeoff and landing accidents, more in-depth guidance on risk management strategies (similar to the depth of topic coverage in the Risk Management Handbook) for a wider variety of ag-specific topics would be beneficial to ag pilots and operators.

The NTSB concludes that risk management guidelines and best practices specific to ag aircraft operations are necessary tools to help operators and pilots mitigate the unique risks associated with their operations. As mentioned previously, the PAASS program development committee possesses industry knowledge and has demonstrated its ability to work with the FAA to develop and widely disseminate training and education materials to the ag operations community. Therefore, the NTSB recommends that the FAA, in conjunction with the NAAREF, develop and distribute ag aircraft operations-specific guidance on risk assessment and mitigation strategies that includes but is not limited to information and checklists for performing preflight and in-flight site surveys, with special emphasis on attention management and obstacle collision avoidance strategies; information on the effects of density altitude, crosswinds, and aircraft weight and balance on aircraft performance during takeoff, landing, and while maneuvering; fuel management; and aerodynamic stall awareness and avoidance. The NTSB also recommends that the NAAREF work with the FAA to develop and distribute this guidance.

[29] NTSB Safety Alert SA-035 can be accessed from the NTSB's Safety Alerts web page at www.ntsb.gov/safety/safety_alerts.html.

# 4. Aircraft Maintenance

Because the aircraft commonly used in ag operations can be decades old with components that have accumulated several thousand hours since new and the low altitudes at which they are flown provide pilots little time to safely respond to any aircraft anomaly or malfunction, proper aircraft maintenance is critical. Aircraft used in ag operations are subject to the maintenance and inspection requirements specified under Part 91 and, if operated over congested areas, the 100-hour, progressive, or program inspections specified under 14 CFR 137.53(c). However, some manufacturers' recommended maintenance instructions, such as those contained in service bulletins (SB) and service information letters (SIL), often are not mandatory maintenance items for aircraft operated under Part 91, which can be a meaningful gap in adequate maintenance because SBs or SILs frequently cover such items as recommended time between overhaul (TBO) and component inspection intervals.[30] Some manufacturers' service manuals and other publications specify a shorter time between inspections for aircraft used in ag operations because such operations are considered a severe operating environment. Components manufactured decades ago may have limited manufacturer support with no recommended TBO or revised maintenance methods provided. For such components, careful maintenance and inspections and following industry best practices can help ensure safety.

A review of the 2013 accidents revealed several examples of improper maintenance and disregard for safety best practices. In one accident involving an Air Tractor AT-502 airplane, the pilot lost effective aileron control of the airplane after the left aileron's push-pull rod and hardware separated in flight. The investigation found that the securing bolts and self-locking nuts were missing after having been improperly torqued by maintenance personnel.[31]

In another accident, the pilot of a Cessna 188B airplane lost effective rudder, tailwheel, and braking control of the airplane after the right rudder pedal assembly separated in flight. The investigation found that the right rudder pedal arm failed due to corrosion as a result of inadequate maintenance and inspection.[32] (See figure 6.) The airplane was also found to be equipped with seat restraints that were more than 40 years old and deteriorating. A Cessna SB specified inspection and replacement intervals for such restraints to minimize the potential for failure.

[30] Although some manufacturers may describe their SBs as mandatory, federal aviation regulations do not specifically require compliance with SBs. However, compliance with SBs that are associated with an airworthiness directive or are referenced in a manufacturer's maintenance manual or instructions for continued airworthiness would be required.

[31] The report for this accident, CEN13LA168, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

[32] The report for this accident, ERA13LA410, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.


**Figure 6.** Damaged rudder pedal of a Cessna 188B airplane.

In an accident involving a Piper PA-36-285 airplane that experienced a total loss of engine power, improper maintenance led to the degradation and deterioration of the No. 2 piston, which was undetected because of overdue maintenance.[33] In an accident involving a Bell 206B helicopter that lost main rotor rpm, maintenance personnel failed to properly tighten the bolts that secured the main driveshaft to the transmission, which resulted in the fatigue failure of the bolts and disconnection of the driveshaft less than 200 flight hours after the maintenance was performed.[34] And, in an accident involving a Bell 45G5 helicopter, a mechanic's inadequate inspection failed to detect fatigue cracking and corrosion originating from a welded surface, which resulted in a failure of a center frame tube aft of the cabin.[35]

The circumstances of these accidents demonstrate the criticality of proper maintenance of aircraft involved in ag operations. The NTSB concludes that a resource that contains detailed information related specifically to agricultural aircraft inspection, maintenance best practices, and quality assurance can reduce the likelihood that unsafe practices may be introduced and perpetuated. Therefore, the NTSB recommends that the FAA, in conjunction with the NAAREF, develop and distribute guidance for ag aircraft operators to assist them in implementing effective aircraft inspection and maintenance quality assurance programs, including but not limited to best practices for performing, recording, and tracking mandatory and recommended maintenance items for each aircraft. The NTSB also recommends that the NAAREF work with the FAA to develop and distribute this guidance.

[33] The report for this accident, CEN13LA280, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

[34] The report for this accident, WPR13LA358, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

[35] The report for this accident, WPR13LA404, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

# 5. Pilot Knowledge and Skills Test Guidance

Although some flight schools and training centers offer ag-specific training, the curricula can vary widely between training providers and operators who provide on-the-job training. Only Part 141 schools have course content minimums for ag-specific courses, which include minimum hour requirements (for both ground and flight training) and specified broad subject areas to be covered.[36] A review of the training backgrounds of the pilots for the accidents occurring in 2013 revealed a variety of training and experience backgrounds. Many pilots accumulated thousands of flight hours and learned their skills on the job, and some received ag-specific training at flight schools or training centers. Some pilots worked in states that have different training and experience requirements than those for the pilots working in other states.[37] Several accidents—including fatal aerodynamic stall accidents—involved experienced pilots who lost control of the aircraft during routine takeoff, landing, or maneuvering operations that should not have presented any extraordinary challenges to a well-trained pilot. Some of these accidents that involved inadequate pilot attention to aircraft performance considerations (such as, aircraft loading, pitch control, or the effects of high density altitude)[38] raise the possibility that some pilots may not have received adequate training.

One accident in which both occupants died involved a private pilot who was receiving instruction from a flight instructor in a Champion 7KCAB airplane as part of a flight school's Agricultural Aviation Basic Operations course. The purpose of the flight, which was the pilot's third in the program, was for the pilot to receive instruction on "ag turns" and how to use a GPS when spraying.[39] Another accident involved the pilot of an Air Tractor AT-502B airplane who decided to continue a takeoff despite the airplane's difficulty becoming airborne. This pilot stated that he added flaps and power with no abnormal indications but, as the airplane reached the expected point of rotation, it was not yet airborne, and he added more flaps. The airplane briefly became airborne but then settled to the ground. The flight manual states that the flaps should be retracted for a normal takeoff. The pilot had about 2,200 hours total flight time with 11 hours of experience in the accident airplane make and model.[40]

Title 14 CFR 137.9(e) requires that pilots who wish to conduct ag aircraft operations demonstrate through knowledge and skills tests that they have satisfactory knowledge and skills to conduct such operations. The knowledge test covers the steps to be taken before starting

[36] The curricula for Part 141 training providers must be approved by the FAA. According to 14 CFR Part 141, Appendix K, an agricultural aircraft operations course must include at least 25 hours of training on agricultural aircraft operations; safe piloting and operating practices and procedures for handling, dispensing, and disposing agricultural and industrial chemicals, including operating in and around congested areas; and applicable provisions of Part 137. The course must also include 15 hours of flight training on agricultural aircraft operations.

[37] Although the NTSB was interested in knowing whether or not the ag operations accidents rates differed across states, there were insufficient flight hour activity data available to perform such an analysis.

[38] The reports for these accidents, CEN13LA448, WPR13LA217, CEN13LA371, CEN13LA463, and CEN13LA472, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

[39] This accident, CEN13FA420, was still under investigation at the time of this report.

[40] The report for this accident, CEN13LA371, can be searched by accident number from the NTSB's Accident Database & Synopses web page at www.ntsb.gov/aviationquery/index.aspx.

operations, including a survey of the area to be worked; the precautions to be observed in using poisons and chemicals and their general effects on plants, animals, and persons; the performance capabilities, operating limitations, and weight and balance limitations of the aircraft; safe flight and application procedures; and other subject areas. The skills test requires the demonstration of select maneuvers in a loaded aircraft, including approaches to the working area, flare-outs, swath runs, pull-ups, turnarounds, and other specified maneuvers. For pilots, the satisfactory completion of the knowledge and skills tests can be determined by the operator (or the operator's designated chief supervisor, if applicable).[41] For supervisors and during the operator's initial Part 137 certification, the knowledge and skills requirements must be demonstrated to an FAA inspector.[42] In many cases, ag aircraft seat only one person; thus, the successful completion of any skills demonstrations must be determined by evaluators on the ground.

FAA guidance about the knowledge test topics and skills test areas for ag operations can be found in AC 137-1A, which describes the knowledge test subject areas, provides sample knowledge test questions (but no answer key), and lists the skills tasks on which the testing candidate will be evaluated. The AC also provides operator-, pilot-, and aircraft-specific guidance and safety procedures information that address many (but not all) of the sample knowledge test topics. The AC does not, however, provide complete explanatory information about the criteria that must be met for satisfactory completion of the skills tasks. The AC suggests that readers refer to several sections of FAA Order 8900.1 for more information, which is publicly available on the FAA website.[43]

The sections of the handbook referenced in AC 137-1A describe the actions that an FAA inspector must take when considering certification eligibility, regulatory compliance, and other FAA areas of responsibility associated with Part 137 operations. Although FAA Order 8900.1 provides additional information (beyond that which is presented in AC 137-1A) about the knowledge test subject topics (including a sample knowledge test with an answer key) and skills test areas, it is primarily an FAA inspector's resource.[44] The information is not optimally organized for use by an ag operator or pilot, and it lacks detail in defining the criteria for the successful completion of some of the tasks for the skills test. For example, the handbook specifies that pull-ups and turnarounds are to be evaluated, but it provides only general guidance as to how those maneuvers should be safely conducted. There are no FAA practical test standards-type guidance materials, detailed best-practices suggestions, or illustrated handbook descriptions of how such maneuvers should be performed safely.

[41] Title 14 CFR 137.41(c) states that a pilot must demonstrate those knowledge and skill requirements to either the certificate holder (operator) or a designated supervisor.

[42] According to 14 CFR 137.41(b), no person may supervise an agricultural aircraft operation unless that person has met the knowledge and skill requirements of 14 CFR 137.19(e). Further guidance for operators is contained in AC 137-1A, section 1-6, paragraphs k and l, and section 2-3, paragraph c. The AC also refers to FAA Order 8900.1, Volume 5, Chapter 11, which provides further information about the FAA inspector's role in determining satisfactory completion of the knowledge and skills requirements.

[43] FAA Order 8900.1 is a handbook that directs the activities of FAA inspectors responsible for the certification, technical administration, and surveillance of various types of operations and aviation activities.

[44] A sample test and answer key nearly identical to the sample provided in the handbook can be accessed from the FAASTeam website at www.faasafety.gov.

Both the AC and the FAA order allow flexibility for operators and FAA inspectors to tailor the knowledge and skills tests to what is appropriate for the geographical area where the operations are conducted, the type of equipment operated, the type of materials dispensed, and other considerations. Both publications note that the FAA inspector who administers the knowledge test may do so in either an oral or written format (if at all, depending on whether or not the pilot has been previously qualified under Part 137), and FAA Order 8900.1 encourages FAA district offices to develop their own written tests and answer keys based on the topics covered in the sample test.[45] Such flexibility allows inspectors to take into consideration necessary updates and any operator-specific factors that need to be covered. However, a lack of more defined criteria for the successful completion of the knowledge and skills tests can allow for variations in how the knowledge and skills items are taught to and understood by pilots.

The NTSB is concerned that a lack of a single source of FAA guidance that contains more detailed information related specifically to the ag operations knowledge test topics and skills tests items can allow for hazardous "norms" to develop, both across the industry and within the training community.[46] For example, an operator or pilot may have a preferred method of performing takeoffs, clean-up swaths, or trim passes that is inconsistent with the procedures specified in established guidance materials, but the operator's preferred method is taught to and used by new pilots. Such a procedural norm could be unsafe and perpetuated within the organization, potentially resulting in an accident. The FAA has observed (and cautions against) the perpetuation of norms in aircraft maintenance organizations and has indicated that adhering to standards and following procedures are effective methods to avoid hazardous norms (FAA 2011, 14-26). The same cautions and avoidance procedures can and should be applied to all facets of ag operations.

The NTSB concludes that standards and procedures are essential for safe operations and, without a resource that contains detailed information related specifically to the ag aircraft operations knowledge test topics and skills test items in existing FAA guidance materials, unsafe, nonstandard practices can be introduced and perpetuated. The NTSB recommends that the FAA, in conjunction with the NAAREF, develop and distribute guidance that covers the Part 137 knowledge test subject areas and skills test items, including but not limited to comprehensive discussions of the knowledge test subject areas and illustrated descriptions of the safe and successful execution of the skills test maneuvers, with special emphasis on aerodynamic stall onset awareness and prevention. The NTSB also recommends that the NAAREF work with the FAA to develop and distribute this guidance.

[45] Because some states or local authorities have additional knowledge, skills, and training requirements, an FAA inspector may accept the results of any state or local knowledge test as a portion of the FAA knowledge test.

[46] Norms are unwritten rules or standard practices that are adopted by a group to solve problems.

# 6. Previous NTSB Safety Action

On May 15, 2013, the NTSB issued safety recommendations to the FAA, the American Wind Energy Association (AWEA), Department of the Interior (DOI), the US Department of Agriculture (USDA), the Department of Defense (DOD), 46 states, 5 territories, and the District of Columbia related to reducing the risk of aircraft conducting low-altitude operations colliding with METs. At the time of this report, the NTSB has received a variety of responses from the safety recommendation recipients. Information about each safety recommendation, recipient responses, and other safety actions are described below.

## 6.1 Safety Recommendations to the FAA

Safety Recommendations A-13-16 and -17 asked the FAA to do the following:[47]

> Amend 14 [CFR] Part 77 to require that all [METs] be registered, marked, and—where feasible—lighted. (A13-16)
>
> Create and maintain a publicly accessible national database for the required registration of all [METs]. (A-13-17)

In an August 1, 2013, response, the FAA stated that its air traffic organization was analyzing the impact of METs on aircraft operations and that it anticipated that its analysis would be complete by September 2013. As a result, both recommendations were classified "Open—Acceptable Response." However, on February 25, 2014, the FAA provided an update and indicated that, due to limited resources and competing priorities, it had not yet completed its analysis. The FAA stated that it would provide an update on its progress by November 2014.

The NTSB understands that the FAA's many congressionally mandated rulemaking projects can strain its rulemaking resources. But the NTSB is concerned that, in the absence of requirements for registering and marking METs, as well as a publicly accessible national MET database, additional MET-collision accidents and loss of life will occur.[48] The NTSB encourages the FAA to complete its analysis and develop a plan for addressing the safety issues identified in these recommendations without further delay.

[47] The NTSB's safety recommendation letter to the FAA can be accessed from the NTSB's Safety Recommendations web page at www.ntsb.gov/safety/safety_recs.html.

[48] Of the three fatal ag-related accidents in 2013 involving an in-flight collision with an obstacle, one involved a collision with a MET; however, the 197-foot tower was marked for conspicuity, and the investigation found that the sun's glare contributed to the pilot's failure to maintain clearance from the MET. See CEN13FA465 for more information about the accident.

## 6.2 Safety Recommendations to the AWEA

Safety Recommendations A-13-18 and -19 asked the AWEA to do the following:[49]

> Revise the *Wind Energy Siting Handbook* to clearly indicate the hazards that [METs] pose to low-altitude aviation operations and encourage voluntarily marking them to increase their visibility by reference to [AC] 70/7460-1, “Obstruction Marking and Lighting.” (A-13-18)

> Inform your members about the circumstances of the airplane accidents that have occurred in connection with the presence of [METs] and emphasize the importance of understanding the aviation safety hazards associated with METs when erecting them. (A-13-19)

On June 24, 2013, the AWEA responded that it is committed to revising the *Wind Energy Siting Handbook* to include a discussion of METs and pilot safety. The AWEA also noted that it raised awareness of this safety issue by sharing the NTSB’s safety recommendation letter with its members. As a result of AWEA’s actions to inform its members about the safety hazards associated with METs, Safety Recommendation was classified A-13-19 “Closed—Acceptable Action.”

Pending AWEA’s issuance of a revised handbook, Safety Recommendation A-13-18 was classified “Open—Acceptable Response” on August 23, 2013.

## 6.3 Safety Recommendation to the DOI, USDA, and DOD

Safety Recommendation A-13-20 asked the DOI, the USDA, and the DOD to do the following:[50]

> As part of your organization’s review and approval of applications to build [METs], provide a copy or direct applicants to [AC] 70/7460-1, “Obstruction Marking and Lighting.

To date, Safety Recommendation A-13-20 is classified “Open—Await Response.”

[49] The NTSB’s safety recommendation letter to the AWEA can be accessed from the NTSB’s Safety Recommendations web page at www.ntsb.gov/safety/safety_recs.html.

[50] The NTSB’s safety recommendation letter to the DOI, the USDA, and the DOD can be accessed from the NTSB’s Safety Recommendations web page at www.ntsb.gov/safety/safety_recs.html.

## 6.4 Safety Recommendation to 46 States, 5 Territories, and the District of Columbia

Safety Recommendation A-13-21 asked 46 states, 5 territories, and the District of Columbia to do the following:[51]

> Enact legislation requiring that [METs] erected in your state or territory are marked and registered in a directory.

Of the 52 recipients of this safety recommendation, 8 (Kentucky, Alaska, Maryland, Michigan, Utah, Washington, Hawaii, and Iowa) have responded to indicate that they have initiated efforts to take action. For these respondents, pending the enactment of legislation to require that METs are marked and registered in a directory, Safety Recommendation A-13-21 is classified "Open—Acceptable Response." For the remaining recipients, Safety Recommendation A-13-21 is classified "Open—Await Response."

## 6.5 Other Previous NTSB Safety Action

While conducting accident investigations, NTSB investigators often work directly with operators, the FAA, and others to accomplish safety action outside the scope of formal safety recommendations. For example, as referenced previously, the operator of a Bell 206B helicopter that collided with power lines amended its policies and procedures manual after the accident as a result of discussions with the NTSB investigator-in-charge.

In March 2011, as a result of the NTSB's investigation of three accidents in which ag airplanes collided with unmarked and unlighted METs, fatally injuring four people, the NTSB issued a safety alert urging pilots involved in low-altitude operations to be vigilant in looking for the towers.[52] This safety alert was widely distributed to the ag community through various aviation media sources.

Following two accidents in 2008 and 2009 involving ag operations helicopter pilots who departed for flight while the helicopter was still connected to fueling and/or loading equipment, NTSB investigators discussed these and previous hot-fueling and hot-loading accidents with the FAA to address the issue. As a result, on November 23, 2010, the FAA issued a safety alert for operators (SAFO) to highlight current guidance and best practices related to hot fueling and hot loading.[53]

[51] At the time that these safety recommendations were issued, four states (Wyoming, North Dakota, Nebraska, and Montana) already required that METs be marked and registered. The NTSB's safety recommendation letter to 46 states, 5 territories, and the District of Columbia can be accessed from the NTSB's Safety Recommendations web page at www.ntsb.gov/safety/safety_recs.html. (The address header for the letter states that the letter was issued to 46 states, 4 territories, and the District of Columbia. However, one territory had been omitted from the distribution inadvertently, and that territory received the letter separately.)

[52] NTSB Safety Alert SA-016, "Meteorological Evaluation Towers," can be accessed from the NTSB's Safety Alerts web page at www.ntsb.gov/safety/safety_alerts.html.

[53] SAFO 10020 can be accessed from the search bar on the FAA's website at www.faa.gov.

# 7. Conclusions

1. Guidance for fatigue management is lacking for agricultural aircraft operations, and such guidance could help operators and pilots develop effective strategies to reduce the likelihood of fatigue, dehydration, hunger, and other physiological factors that can negatively affect a pilot's concentration, decision-making, and performance.

2. Risk management guidelines and best practices specific to agricultural aircraft operations are necessary tools to help operators and pilots mitigate the unique risks associated with their operations.

3. A resource that contains detailed information related specifically to agricultural aircraft inspection, maintenance best practices, and quality assurance can reduce the likelihood that unsafe practices may be introduced and perpetuated.

4. Standards and procedures are essential for safe operations and, without a resource that contains detailed information related specifically to the agricultural aircraft operations knowledge test topics and skills test items in existing Federal Aviation Administration guidance materials, unsafe, nonstandard practices can be introduced and perpetuated.

# 8. New Safety Recommendations

As a result of this safety report, the National Transportation Safety Board makes the following safety recommendations:

**To the Federal Aviation Administration:**

In conjunction with the National Agricultural Aviation Research & Education Foundation, develop and distribute agricultural aircraft operations-specific guidance on fatigue, fatigue management strategies, and scheduling practices to help reduce the likelihood of fatigue, dehydration, hunger, and other physiological factors that can negatively affect a pilot's concentration, decision-making, and performance. (A-14-024)

In conjunction with the National Agricultural Aviation Research & Education Foundation, develop and distribute agricultural aircraft operations-specific guidance on risk assessment and mitigation strategies that includes but is not limited to information and checklists for performing preflight and in-flight site surveys, with special emphasis on attention management and obstacle collision avoidance strategies; information on the effects of density altitude, crosswinds, and aircraft weight and balance on aircraft performance during takeoff, landing, and while maneuvering; fuel management; and aerodynamic stall awareness and avoidance. (A-14-025)

In conjunction with the National Agricultural Aviation Research & Education Foundation, develop and distribute guidance for agricultural aircraft operators to assist them in implementing effective aircraft inspection and maintenance quality assurance programs, including but not limited to best practices for performing, recording, and tracking mandatory and recommended maintenance items for each aircraft. (A-14-026)

In conjunction with the National Agricultural Aviation Research & Education Foundation, develop and distribute guidance that covers the 14 *Code of Federal Regulations* Part 137 knowledge test subject areas and skills test items, including but not limited to comprehensive discussions of the knowledge test subject areas and illustrated descriptions of the safe and successful execution of the skills test maneuvers, with special emphasis on aerodynamic stall onset awareness and prevention. (A-14-027)

**To the National Agricultural Aviation Research & Education Foundation:**

Work with the Federal Aviation Administration to develop and distribute agricultural aircraft operations-specific guidance on fatigue, fatigue management strategies, and scheduling practices to help reduce the likelihood of fatigue, dehydration, hunger, and other physiological factors that can negatively affect a pilot's concentration, decision-making, and performance. (A-14-028)

Work with the Federal Aviation Administration to develop and distribute agricultural operations-specific guidance on risk assessment and mitigation strategies that includes but is not limited to information and checklists for performing preflight and in-flight site surveys, with special emphasis on attention management and obstacle collision avoidance strategies; information on the effects of density altitude, crosswinds, and aircraft weight and balance on aircraft performance during takeoff, landing, and while maneuvering; fuel management; and aerodynamic stall awareness and avoidance. (A-14-029)

Work with the Federal Aviation Administration to develop and distribute guidance materials for agricultural aircraft operators to assist them in implementing effective aircraft inspection and maintenance quality assurance programs, including but not limited to best practices for performing, recording, and tracking mandatory and recommended maintenance items for each aircraft. (A-14-030)

Work with the Federal Aviation Administration to develop and distribute guidance that covers the 14 *Code of Federal Regulations* Part 137 knowledge test subject areas and skills test items, including but not limited to comprehensive discussions of the knowledge test subject areas and illustrated descriptions of the safe and successful execution of the skills test maneuvers, with special emphasis on aerodynamic stall onset awareness and prevention. (A-14-031)

## BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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**Adopted: May 7, 2014**

# 9. Appendix

| Date | NTSB No. | Aircraft | Injury severity | FAR | Obstacle collision? | Fatigue? | Mechanical issues? | Additional information |
|---|---|---|---|---|---|---|---|---|
| 1/2/13 | WPR13FA080[i] | Bell 206 | fatal (1) | 91 | | | | Vineyard frost protection; spatial disorientation, dark night with fog |
| 1/3/13 | WPR13CA084[i] | Bell 47G | minor (1) | 137 | yes | | | Telephone pole |
| 1/8/13 | WPR13LA087 | Bell OH-58C | serious (1) | 137 | | | yes | Reported uncommanded right-rolling tendency |
| 1/31/13 | CEN13LA152 | Air Tractor AT-401 | none | 137 | | | yes | Engine power section failure |
| 2/7/13 | CEN13LA168 | Air Tractor AT-502 | minor (1) | 91 | | | yes | Maintenance test flight; aileron rod separated, improperly torqued nuts |
| 2/10/13 | WPR13CA120[i] | Bell 206B | none | 137 | | | | Improper fuel management |
| 2/15/13 | ERA13LA138 | Ayres S2R-T34 | none | 137 | | | | Fuel starvation due to debris in fuel control unit |
| 2/16/13 | CEN13LA163 | PZL Mielec M-18A | fatal (1) | 137 | yes | | | Guy wires |
| 2/18/13 | WPR13GA128 | Bell 206B | fatal (1) | Public | yes | yes | | Seeding flight; struck static line, pilot task-and/or work-related fatigue |
| 2/24/13 | ERA13CA163[i] | Air Tractor AT-301 | none | 137 | yes | | | Tree |
| 3/8/13 | CEN13LA191 | Grum/Schw G-164B | minor (1) | 137 | | | | Loss of control during takeoff |
| 4/24/13 | CEN13LA239 | Air Tractor AT-301 | none | 91 | | | yes | Engine supercharger bearing failure |
| 5/2/13 | WPR13LA217 | Robinson R44 II | none | 137 | | | | Over max gross weight; spray tank visual sight glass design was factor |
| 5/4/13 | WPR13LA215 | Arrow OH-58A+ | none | 137 | | yes | | Terrain collision in dark night; pilot fatigue |
| 5/5/13 | CEN13FA259 | Piper PA-25-235 | fatal (1) | 137 | | | | Proficiency demonstration flight; loss of control likely due to sudden cardiac event |
| 5/5/13 | CEN13LA263 | Air Tractor AT-602 | none | 137 | yes | | | Power line |
| 5/7/13 | CEN13LA260 | Cessna A188B | minor (1) | 137 | | | | Fuel contamination (water); inadequate preflight |
| 5/8/13 | CEN13LA265 | Air Tractor AT-301 | none | 137 | | | | Pilot diverted attention due to door hinge failure; airplane settled into crop |
| 5/8/13 | CEN13LA283 | Air Tractor AT-302 | none | 91 | | | | Operation with known fuel system-related maintenance discrepancy; fuel starvation |
| 5/9/13 | WPR13LA223 | Schweizer G-164B | fatal (1) | 91 | yes (ground) | | | Repositioning flight; struck runway service equipment and operator |
| 5/10/13 | ERA13LA236 | Bell 206B | none | 137 | yes | | | Power line |

| Date | NTSB No. | Aircraft | Injury severity | FAR | Obstacle collision? | Fatigue? | Mechanical issues? | Additional information |
|---|---|---|---|---|---|---|---|---|
| 5/14/13 | CEN13LA280 | Piper PA-36-285 | minor (1) | 137 | | | yes | No. 2 piston deterioration; improper and overdue maintenance |
| 5/15/13 | WPR13LA233 | Schweizer G-164D | minor (1) | 137 | | yes | | Loss of control in wake turbulence; pilot fatigue due to hours awake, workload |
| 5/15/13 | WPR13LA230[ii] | Cessna T188C | none | 91 | | | | |
| 5/23/13 | CEN13LA293 | Air Tractor AT-602 | none | 137 | | | | Fuel exhaustion; inadequate preflight planning |
| 5/24/13 | WPR13LA248 | Air Tractor AT-301 | none | 137 | | | | Fuel exhaustion; inadequate fuel planning |
| 6/1/13 | CEN13LA323 | Rockwell S-2R | minor (1) | 137 | | | | Decision to land in crosswind that exceeded airplane's capabilities |
| 6/6/13 | CEN13FA324 | Weatherly 620B | fatal (1) | 137 | | yes | | Loss of control, inadvertent stall, pilot task-and/or work-related fatigue |
| 6/6/13 | CEN13LA322 | Grum/Schw G-164B | none | 137 | | | | Failure to climb after takeoff |
| 6/8/13 | CEN13LA341 | Air Tractor AT-301 | none | 137 | | | | Partial loss of engine power |
| 6/12/13 | CEN13LA390[ii] | Rockwell S-2R | none | 137 | | | | |
| 6/16/13 | CEN13LA353 | Air Tractor AT-802A | serious (1) | 137 | yes | | | Trees |
| 6/19/13 | CEN13FA357 | Bell 47-G-3B-1 | fatal (1) | 137 | | | | Loss of control in flight |
| 6/23/13 | CEN13LA371 | Air Tractor AT-502B | none | 137 | | | | Decision to continue takeoff; high density altitude |
| 6/24/13 | WPR13LA287 | Bell 206B | serious (1) | 91 | yes | | | Cherry tree-drying flight; skid caught in tree netting |
| 6/26/13 | CEN13LA375 | Air Tractor AT-301 | none | 137 | | | | Loss of engine power |
| 6/28/13 | CEN13LA379 | Piper PA-25-235 | none | 137 | | | | Reduced braking efficiency during landing; delayed decision to go around |
| 6/28/13 | CEN13LA384 | Ayres S2R-T34 | none | 137 | | | yes | Right main landing gear; improper weld repair and corrosion |
| 6/29/13 | ERA13LA312 | Schweizer G-164B | none | 137 | | | yes | Right main landing gear wheel rim failure |
| 6/30/13 | CEN13LA520 | Piper PA-25-235 | none | 137 | | | | Failure to maintain control during landing |
| 7/2/13 | CEN13LA391 | Air Tractor AT-402B | none | 137 | | | | Inadequate airspeed; stall during takeoff |
| 7/3/13 | WPR13LA308 | WSK PZL Mielec M-18B | none | 137 | | | | Continued takeoff in tailwind; delayed action to dump chemical load |
| 7/3/13 | CEN13LA402 | Air Tractor AT-502B | none | 137 | | | yes | Loss of throttle control during takeoff due to unsecured throttle control pin |
| 7/4/13 | CEN13LA394 | Gulf/Schw G-164B | minor (1) | 137 | yes | | | Tree |

| Date | NTSB No. | Aircraft | Injury severity | FAR | Obstacle collision? | Fatigue? | Mechanical issues? | Additional information |
|---|---|---|---|---|---|---|---|---|
| 7/6/13 | CEN13LA395 | Bell 46G-3B-1 | minor (1) | 137 | | | | Failure to maintain proper engine rpm |
| 7/8/13 | ERA13LA318 | Grum/Schw G-164B | none | 137 | | | yes | Right brake failure |
| 7/10/13 | CEN13LA414 | Ayres S2R-T41 | minor | 91 | | | yes | Improper rigging of propeller governor linkage |
| 7/15/13 | CEN13LA473[ii] | Air Tractor AT-502B | none | 137 | | | | |
| 7/17/13 | CEN13LA422 | Grum/Schw G-164A | serious (1) | 137 | yes | | | Trees |
| 7/18/13 | CEN13FA420[i, ii] | Champion 7KCAB | fatal (2) | 91 | | | | |
| 7/19/13 | CEN13LA424 | Air Tractor AT-802A | serious (1) | 137 | yes | | | Power line |
| 7/19/13 | CEN13LA425 | Air Tractor AT-400 | none | 137 | yes | | | Guy wires |
| 7/19/13 | CEN13LA447 | Bell 206B | none | 137 | | | | Terrain clearance not maintained |
| 7/20/13 | CEN13LA426 | Air Tractor AT-502 | none | 137 | | | | Wind shift during takeoff |
| 7/24/13 | CEN13LA436 | Texas Heli OH-13E/M74 | none | 137 | | | | Failure to maintain control in flight |
| 7/28/13 | CEN13LA448 | Robinson R44 | serious (1) | 137 | | | | Failure to maintain rotor speed |
| 7/29/13 | CEN13LA444 | Eagle DW-1 | none | 137 | yes | | | Tree, misjudged height |
| 7/29/13 | CEN13LA442 | Texas Heli OH-13H/M74A | none | 137 | | | | Diverted attention; impacted corn field |
| 7/29/13 | CEN13LA443 | Grumman G-164A | none | 137 | | | yes | Partial loss of engine power; exhaust rocker housing failure due to excessive torque loading |
| 7/29/13 | CEN13LA451 | Air Tractor At-400a | minor (1) | 137 | | | | Failure to maintain control during takeoff |
| 8/4/13 | WPR13LA358 | Bell 206B | minor (1) | 137 | | | yes | Failure to properly tighten bolts resulted in fatigue failure of bolts, driveshaft disconnection |
| 8/4/13 | CEN13LA472 | Air Tractor AT-301 | minor (1) | 137 | | | | Failure to maintain proper pitch control; altitude too low for recovery |
| 8/5/13 | CEN13FA465 | Air Tractor AT-400 | fatal (1) | 137 | yes | | | MET; sun glare was a factor |
| 8/6/13 | CEN13LA464 | Piper PA-36-300 | none | 137 | yes | yes | | Tree, decision to accept high-risk job; pilot fatigue due to interrupted sleep |
| 8/6/13 | CEN13LA463 | Bell 47G-3B-1 | none | 137 | | | | High gross weight, high density altitude; decision-making |
| 8/9/13 | CEN13LA486 | Air Tractor AT-400 | none | 91 | | | | Maintenance test flight; failure to maintain directional control during landing |
| 8/12/13 | CEN13LA484[ii] | Rockwell Int S-2R | none | 137 | | | | |
| 8/22/13 | CEN13LA504 | Gulf/Schw G-164B | none | 137 | | | | Failure to properly set engine power for takeoff |

| Date | NTSB No. | Aircraft | Injury severity | FAR | Obstacle collision? | Fatigue? | Mechanical issues? | Additional information |
|---|---|---|---|---|---|---|---|---|
| 8/28/13 | CEN13LA568 | Air Tractor AT-802 | none | 137 | | | yes | Failure of fuel control unit bearing; fuel starvation |
| 9/4/13 | ERA13LA410 | Cessna 188B | minor (1) | 137 | | | yes | Right rudder pedal arm failure in flight; inadequate maintenance and inspection |
| 9/4/13 | CEN13LA551 | Grum/Schw G-164B | none | 137 | | | yes | Uncommanded brake application due to loose valve |
| 9/6/13 | CEN13LA533 | Grumman G-164A | minor (1) | 137 | | | | High density altitude, reduced climb performance, delay releasing product |
| 9/6/13 | CEN13LA537 | Cont Copters MK5A | none | 137 | | | | Loss of control when pilot removed hand from collective to plug in radio connection |
| 9/11/13 | WPR13LA404[ii] | Bell 47G5 | none | 137 | | | | |
| 9/25/13 | CEN13LA561[i, ii] | Weatherly 620 | none | 91 | | | | |
| 9/29/13 | WPR13LA429 | Texas Heli OH-13E/M74 | minor (1) | 137 | yes | | | Transmission wires |
| 10/1/13 | WPR14CA002 | Air Tractor AT-401 | none | 137 | | | | Failure to maintain directional control during takeoff in gusting wind |
| 10/1/13 | WPR14CA003 | Air Tractor AT-402B | none | 137 | | | | Distracted attention; failure to maintain terrain clearance, dark night |

[i] Accident not subject to additional data collection for this report.
[ii] Accident investigation not completed at the time of this report.

# 10. References

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