

Loss-of-Control In-Flight Mitigation through Installation of Stability Augmentation and Autopilot Systems in Light Helicopters

Report

Helicopter Safety Enhancement No. 70 Output No. 3

Prepared by H-SE-70 Team in partial fulfillment of USHST efforts to encourage use of technologies that can reduce the risk of fatal helicopter accidents

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United States
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Prepared for the USHST for promotion through industry stakeholders and safety advocates

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1. Background

The US Helicopter Safety Team (USHST) is a volunteer team of US government and industry stakeholders formed to improve the safety of civil helicopter operations in the National Airspace System. The USHST's vision is a civil US registered helicopter community with zero fatal accidents. Through data-driven accident and flight safety data analyses, the USHST's mission is to understand the US helicopter community's safety issues and use that understanding to promote the development and implementation of voluntary, consensus-based risk mitigations called helicopter safety enhancements (H-SEs). This document provides us with a clear example of how the USHST can leverage industry partnerships to develop, implement, and promote helicopter safety enhancements (H-SEs) that can reduce US civil helicopter fatal accident rates. For additional information about the USHST, refer to [Annex E](#).

2. Scope

The USHST established H-SE 70: Stability Augmentation System (SAS) / Autopilot as a desired safety enhancement that recommended technology and equipment solutions to reduce fatal rotorcraft accidents. The initial scope summary stated: "Industry and Federal Aviation Administration (FAA) to encourage development and installation of a stability augmentation system (SAS) and/or autopilot in light helicopters."

While several concurrent USHST efforts seek to address other critical safety enhancements, this white paper focuses on the continued development and integration of stability augmentation and autopilot systems in rotorcraft. Emerging technology solutions can reduce the complexity, weight, and cost of traditional automatic flight control systems.

The Statement of Work (SOW) for this H-SE specifically stated the following:

The USHST Safety Analysis Team identified loss of control in flight (LoC-I) as one of the top three most common occurrence categories of fatal civil helicopter accidents in their 2009-2013 dataset. Current light helicopters have flight characteristics that are challenging and demanding of pilot workload. The purpose of this H-SE is to increase safety by encouraging the development and installation of a stability augmentation system (SAS) or autopilot devices that increase the flight stability of light helicopters.

SAS/autopilot devices must be designed to reduce the incidence of loss of control in flight (LoC-I) and should consider new and retrofit configurations not currently supported by similar devices. The devices should also consider low visibility, low ceilings, and unintended IMC, and preferably enhance safety without requiring pilot action. A SAS/autopilot device may embody commercial off-the-shelf (COTS) pneumatic, electronic, micro-electromechanical systems (MEMS), or mechanical devices to sense or control helicopter motion.

The following SOW outputs, described as performance goal indicators, were identified for H-SE 70:

1. USHST to coordinate the formation of the H-SE 70 team.

2. Meet with the FAA regarding certification pathways for SAS/autopilot technology for light helicopters.
3. Draft a white paper that identifies the need and pathways to certification for SAS/autopilot technology for light helicopters. White paper should discuss available options as well as future technological needs.
4. Promote the white paper to the FAA (including Parts 27/29 rewrite working groups) and industry.

Note 1: The H-SE 70 team modified the scope slightly to focus solely on Part 27 integration to improve the likelihood of follow-on FAA action. Some information may, however, facilitate future efforts of Part 29 stakeholders seeking similar objectives.

Note 2: The USHST acknowledges that further refinement and implementation of concepts, solutions, and capabilities proposed in this document require joint development by qualified government and industry stakeholders.

3. Introduction

Helicopters are generally more prone to loss-of-control (LoC) accidents than airplanes due to their inherent instability and lack of mechanical trim. Most airplanes certified under FAA requirements are typically designed with inherent stability and trim characteristics, requiring no additional augmentation or automatic flight control system, such as an autopilot. Consequently, in moments of disorientation, a fixed-wing pilot can release the flight controls, and the airplane will not diverge in attitude, generally returning to its last trim condition. In other words, an aircraft trimmed for straight and level flight will tend to return to this trim condition, following a response from an external force (such as a wind gust) or pilot displacement of the flight controls away from trim.

Rotorcraft, on the other hand, lack inherent stability and trim characteristics that result from many basic design factors. For example, the geometry of and interaction between the main and tail rotors can have a strong influence on stability and coupling in all axes (i.e., between pitch, roll, yaw, and collective, and combinations of each). Such coupling can be strongly influenced by airspeed and aircraft configuration (e.g., installation of external equipment). Additionally, hydraulic systems are commonly used and often required in rotorcraft to reduce pilot control forces to a manageable level. However, with the introduction of hydraulics, the aircraft has no inherent trim system, which must be further introduced if stability is required.

Under visual meteorological conditions (VMC), the need for inherent stability and trim are not essential nor required for certification, although pilot workload may be higher without them. However, as visual conditions deteriorate, as under special visual flight rules (SVFR), the need for stability and trim becomes increasingly essential. Many LoC-I accidents resulting from disorientation share the same entry condition: a climbing turn, with a loss of airspeed occurring before losing aircraft control. [Annex C](#) details several examples of rotorcraft LoC-I accidents investigated by the National Transportation Safety Board (NTSB). Under instrument meteorological conditions (IMC) where no visual cues exist, the FAA specifies a set of criteria (*14 CFR 27, Appendix B*) that includes requirements for trim, static stability, and dynamic stability. To achieve these trim and stability requirements, integrating an automatic flight control system (AFCS), which may include a SAS and/or autopilot, has been traditionally used. In such

cases, *Appendix B to Part 27* provides additional criteria to ensure the reliability of equipment to operate safely under instrument flight rules (IFR).

It follows that, if all rotorcraft are designed to meet some of the IFR stability requirements, many LoC-I accidents could be avoided, as the aircraft stability would help the pilot maintain positive control during temporary losses of visual cueing or disorientation. With the increasing maturity of existing technology and the emergence of new technologies commonly used beyond the aerospace industry, it may be possible to find new AFCS solutions that achieve sufficient stability and reliability through low-cost/low-weight systems. Some systems already exist on the market, but certification of these systems has often proved challenging, which ultimately makes the cost unaffordable to helicopter operators, despite their safety benefits.

As noted above, AFCS are generally grouped into two classes: stability augmentation systems (SAS) and autopilots. While AFCS have varying levels of complexity and functionality, they are typically designed to reduce pilot workload and increase situational awareness, allowing the pilot to focus greater attention on other flight tasks, such as traffic and obstacle avoidance, navigation, air traffic control (ATC) communication, and weather monitoring. At their most basic level, AFCS provide trim and short-term stability. More-complex systems offer long-term stability, dynamic stability, and attitude retention. Finally, the most sophisticated systems provide coupling to other aircraft systems so that the pilot can fly hands-off to commanded heading, altitude, airway, or instrument approach, for example.

Autopilots have varying levels of control and various functions, but generally, an autopilot is a system that will control the aircraft's attitude without pilot input. Typically, autopilots can also hold the aircraft on a heading or altitude; many systems have more-advanced functions. The pilot can set the autopilot, and it will fly the aircraft. [Annex A](#) provides a general description of typical AFCS commonly integrated today into rotorcraft.

To summarize, AFCS have been successfully integrated into transport category (Part 29) helicopters for more than 30 years and have proven their effectiveness and safety for flight in IMC. However, most of these systems are too complex or heavy to integrate into normal category (Part 27) helicopters, particularly single-engine models. Consequently, these smaller rotorcraft lack the operational capability and inherent safety the AFCS provide, restricting such aircraft from operating under IFR and resulting in more frequent flights under VFR conditions having poor visibility and low ceilings. Since most Part 27 aircraft are not equipped with even the most basic stabilization systems, they remain more susceptible to LoC-I when operations are conducted under marginal VFR or when a pilot encounters UIMC/IIMC. More than half of the accidents cited in [Annex D](#) of this report can be attributed to such conditions. Therefore, this paper focuses on leveraging new AFCS solutions that achieve sufficient stability and reliability through relatively simple, lightweight AFCS.

4. Safety Data

In 2016, the USHST adopted an approach to accident analysis to align itself with the Commercial Aviation Safety Team (CAST) and General Aviation Joint Steering Committee (GAJSC). The USHST tasked its Safety Analysis Team (SAT) with analyzing NTSB data from 104 fatal helicopter accidents between 2009 and 2013, assigning a single occurrence category using a taxonomy consistent with CAST/ICAO

methodologies. Based on this analysis, the SAT found that the three most common occurrence categories were:

- A. **Loss of Control – In Flight (LoC-I):** Loss of aircraft control while, or deviation from intended flight path, in flight. Loss of control in flight is an extreme manifestation of a deviation from the intended flight path. The term “loss of control” may cover only some cases during which an unintended deviation occurred.
- B. **Unintended Flight in IMC (UIMC):** Unintended flight into instrument meteorological conditions (IMC) includes accidents previously linked to inadvertent instrument meteorological conditions (IIMC).
- C. **Low-Altitude Operations (LALT):** Collision or near-collision with obstacles/objects/terrain while intentionally operating near the surface (excludes takeoff or landing phases).

The SAT analysis determined that these three fatal accident categories together accounted for half (52) of all fatal accidents analyzed and were responsible for more fatalities (104) than the remaining 15 categories combined (96).

Table 1 below summarizes eight fatal accidents that resulted from one of these three occurrence categories. [Annex D](#) provides a summary of the NTSB final report for each accident.

Table 1: NTSB Accident Reports Supporting H-SE 70

Ref	Accident Report No.	Accident Summary
1	WPR10FA055	2009 Doyle, CA: Loss of control in flight; 3 fatal
2	CEN13FA003	2012 Intracoastal City, LA: VFR encounter with IMC; 1 fatal
3	CEN13FA010	2012 Blanco, TX: Loss of control in flight; 3 fatal
4	WPR13FA080	2013 Delano, CA: Loss of visual reference; 1 fatal
5	ERA09FA537	2009 Georgetown, SC: VFR encounter with IMC; 3 fatal
6	ERA13FA273	2013 Manchester, KY: Loss of control in flight; 3 fatal
7	CEN11FA468	2011 Rising Sun, IN: Loss of visual reference; 1 fatal
8	WPR13GA128	2013 Eureka, NV: Low-altitude operation; 1 fatal

5. Historical Context – IFR Certification

The legacy of IFR certification began in the 1970s when criteria were first proposed that would enable rotorcraft to operate under IFR. When first published in 1965, Part 27 and Part 29 (which had their basis in Civil Aviation Regulation [CAR] 6 and CAR 7, respectively) had no certification requirements for IFR. Consequently, all rotorcraft were limited to VFR. In 1975, the FAA published Special Federal Aviation Regulation (SFAR) 29-1, *FAA Study of Limited IFR Operations in Rotorcraft*, which would allow for limited IFR operations of certain transport category rotorcraft through the establishment of a limited IFR category. The study targeted several factors to be considered in its evaluation, including flight characteristics and equipment requirements, operating procedures and limitations, flight crew requirements, and training requirements. In particular, the FAA considered the following factors as they pertain to aircraft certification:

- The inherent characteristics of the rotorcraft to be operated, including flight characteristics, performance, approach speed, and ability to terminate an approach
- The duality, redundancy, and independence of equipment in the rotorcraft, including controls, flight instruments, electrical, communication and navigation systems, and power and fuel systems.

SFAR 29-1 was amended four times, notably in January 1979, when normal category (Part 27) rotorcraft were also included within its scope. The FAA additionally established a Rotorcraft Regulatory Review Program (RRRP) at this time, which was tasked to conduct a comprehensive review of rules regarding rotorcraft airworthiness standards and operating requirements. In 1983, the FAA formally amended Part 27 and Part 29 to include Appendix B, *Airworthiness Criteria for Helicopter Instrument Flight*. Consistent with the charter of the RRRP, the appendix includes requirements for trim, static and dynamic stability, stability augmentation systems, and the installation of systems and equipment. It is noteworthy that the Part 27 stability requirements differentiate between single- and dual-pilot IFR approvals.

When considering the installation of systems and equipment from a practical application standpoint, Part 27, Appendix B can be viewed by asking the following question:

- If a single critical system fails during a flight in IMC, can the aircraft safely reach its destination, execute the instrument approach procedure and the missed approach procedure, and then continue to the alternate destination without exceptional pilot skill, alertness, or strength?
- If the answer is no, then the system requires additional robustness, either through redundancy or improved reliability.

6. AFCS Functionality

There are several ways in which an AFCS may be integrated into rotorcraft. [Annex A](#) provides an overview of how typical AFCS have been traditionally implemented; other novel solutions, such as fly-by-wire, are generally considered too complex (and expensive) to be presented in the context of Part 27 aircraft. Consequently, this white paper focuses more on AFCS functionality and performance rather than specific design criteria that promote the use of new and emerging technology.

The following functions may be considered when integrating an AFCS into a rotorcraft. The functions are generally listed with increasing complexity, which may affect other design requirements, cost, and weight. The first two functions may be considered essential in reducing the accident categories detailed in Section 4. The remaining functions, while designed for a particular operating environment, may also have significant utility in reducing accidents while also reducing pilot workload and increasing situational awareness.

6.1 Basic AFCS Functionality

A. Trim

A force gradient trim system provides a fundamental, significant first step in providing a safety benefit. Many LoC-I or UIMC accidents have a pattern of control movement believed to result from the pilot unintentionally changing control positions when attention is diverted to another task. Force gradient

systems can therefore provide strong, nonvisual cues that prevent the pilot from unintentionally changing flight control positions (with corresponding changes in aircraft attitude and airspeed).

B. Stability Augmentation Systems (SAS)

Stability augmentation builds upon trim control by providing short- and/or long-term aircraft stability. Basic stability augmentation consists of simple rate damping, in which the SAS attempts to counter external disturbances (such as a wind gust) or to damp a pitch, roll, or yaw rate. More-advanced SAS systems also provide long-term attitude stability or attitude retention by maintaining a commanded pitch and roll attitude. Such systems may also provide yaw correction, in which the AFCS provides a yaw control input to damp yaw rates and minimize lateral acceleration (i.e., maintain ball centered flight).

It is worth noting that prolonged IFR flights (e.g., cruise, holding, approach, missed approach, etc.) have been successfully demonstrated with an acceptable pilot workload, even for single-pilot operations, for degraded AFCS solutions limited to a backup SAS. Without any AFCS assistance, the pilot workload would be rated excessively high in these conditions. Although such evaluations were performed by IFR-qualified pilots, the significant difference in workload clearly demonstrates the benefits of a simple SAS solution when outside visibility becomes poor or UIMC is encountered.

C. Basic Coupled Modes

Basic coupled modes reduce pilot workload by maintaining one or more aircraft states, selected by the pilot as a function of internal aircraft sensors, such as heading, altitude, or airspeed. These traditional modes, which may be used under VFR or IFR, include:

- **Heading (Track) hold**
- **Airspeed (Ground Speed) hold ***
- **Altitude hold ***
- **Vertical Speed (Flight Path Angle) hold. ***

* Note that these modes could be utilized with a 3- or 4-axis AFCS, but with a different implementation. For example, with a 3-axis system, **Airspeed** or **Altitude** may be engaged, but not simultaneously. With a 4-axis AFCS, Airspeed and Altitude may both be engaged together.

In terms of the objectives of this white paper, the basic AFCS functions described above may be viewed as fundamental in providing the safety benefits needed to reduce accidents resulting from LoC-I, UIMC, and LALT. They also offer the least complex, lightest, and cheapest solutions. Nevertheless, more-advanced AFCS functions may further contribute to safety in a meaningful way, as described in the following section.

6.2 Advanced AFCS Functionality

A. IFR Coupled Modes

Advanced modes extend the concept of basic coupling by integrating the AFCS to an external navigation source to provide guidance from ground-based navigation aids or GPS. Examples include:

- **Navigation:** Lateral guidance from VOR, VORTAC, GPS, etc.
- **Approach:** Lateral and vertical guidance from approach systems such as ILS, LOC/GS, or LPV

- **Go-Around:** Wings-level climb, following a missed approach
- **Hold:** Lateral guidance to enter and hold in a published holding pattern
- **Approach to Hover:** Automatic approach to hover, following an instrument approach (4-axis AFCS required).

These modes have been historically found only in IFR-certified autopilots, based on their associated certification requirements. Nevertheless, they may bring significant safety benefits for VFR operation through workload reduction, the ability to recover from IIMC, or the ability to conduct IFR training/maintain IFR proficiency. For these reasons, many Part 27 VFR-only systems are including these modes in their designs.

B. Additional Safety-Enhancing Modes

The following modes and features are specifically intended for safety enhancement. These modes can be incorporated to support either VFR or IFR operations or to assist the pilot in high-workload environments. However, their integration may require the installation of additional sensors or equipment (such as inertial rate gyros, air data computers, GPS, etc.), which may significantly increase their complexity. They include:

- **Envelope Protection:** This mode is designed to work in the background continuously (i.e., pilot activation not required) and provide feedback to the pilot that he or she is approaching one or more key aircraft state parameters or limitations, such as:
 - Airspeeds: Velocity – Never Exceed (V_{NE}), Best Rate of Climb Speed (V_V), Instrument Flight Minimum Speed (V_{MINI})
 - Aircraft Attitude: maximum pitch and roll angle
 - Transmission and Engine Limits: maximum takeoff power, maximum continuous power, and one engine inoperative (OEI) power (30-second and two-minute).
- **Level or Save Me:** This mode assists the pilot in recovering the aircraft to a wings-level attitude should the pilot encounter spatial disorientation or an unusual attitude. When selected by the pilot, this mode, in its most basic form, automatically provides the control inputs necessary to achieve a level flight attitude. More-advanced forms of this mode may provide constant heading and airspeed, while the incorporation of a 4-axis AFCS (incorporating collective control) can establish a constant altitude or nominal rate of climb. Features such as this can be a significant aid in recovering from an impending loss of control in UIMC incidents or in recovering from an unusual attitude in a degraded visual environment. In order to be most effective, the pilot must be able to easily engage the feature with minimum effort and control actions (simple button push) or, for example, by integrating the activation device into one of the primary flight controls.
- **Integration with Safety-Enhancing Equipment:** The AFCS can be integrated with other safety systems, such as terrain awareness or traffic avoidance systems. When such systems activate an alert, the AFCS could assign a priority command (i.e., override any AFCS modes previously selected by the pilot) to maneuver the aircraft to deconflict the alert. For example, if the AFCS were coupled with NAV and ALT engaged but received an alert from an integrated safety system, the AFCS would automatically adjust the flight profile to deconflict the alert until it no

longer existed, at which time the AFCS could revert back to its previous state. The display of additional information might also be required, providing the pilot with the situational awareness to allow an automated function to continue or override the AFCS while responding to a higher-priority in-flight hazard or task.

- **Auto-Land:** This mode is designed to assist the pilot or autonomously land the helicopter under emergency conditions, such as brown-out or white-out conditions, when visual references are temporarily lost. Note that implementation of this mode is extremely complex, requiring the use of sophisticated attitude, position, and other external sensors; its implementation to date has only been used with military applications.
- **Hover-Assist:** Maintain a heading and hovering position or a reference ground speed. Autopilot systems that include collective control can also provide a radar-altimeter hover height hold function. These features can provide a significant reduction in the hazards associated with loss of control during momentary white-out or brown-out conditions when visual references are temporarily lost.
- **Automatic Hover Departure:** Similar to **Go-Around**, this mode provides a hands-off or limited hands-on departure when departing from a hover, with a wings-level takeoff and climb from a hover, which could be used for instrument departures or for Category A operations. This mode can also be activated in response to brown-out, white-out, or other loss-of-visual-reference scenarios during a hover to perform a controlled climb to visual conditions.
- **Autorotation Assistance:** Upon detection of engine failure, the system can automatically provide prompt control inputs such as lowering the collective and pitching the aircraft for optimum autorotation airspeed. This type of automation can provide a significant safety increase by reducing the risk of dangerous rotor speed decay and helping the pilot perform a successful autorotation.

Note that, beyond trim, SAS, and basic coupled modes, the available functionality and reliability will largely depend on AFCS complexity (i.e., 2-axis, 3-axis, or 4-axis), the type and number of external sensors to be integrated (GPS, radar-altimeter, heading, TCAS, etc.), and system design assurance levels. These factors may, in turn, play a significant role in cost and weight.

Additionally, it is important to note that modes that require a fourth axis may significantly increase system complexity, reliability, and monitoring requirements. For example, integration with the engine FADEC may be required to prevent engine/gearbox exceedances. Nevertheless, while these more-advanced systems can provide impressive hands-off capabilities, a system does not have to be approved for hands-off operation in order to provide a significant safety benefit. Approval for hands-off operation may require additional safety considerations to achieve certification.

7. AFCS Performance and Safety Considerations

The FAA generally considers any system that connects to the helicopter flight controls to be a critical system, requiring careful consideration of the safety aspects of its integration. In short, a safety assessment must consider the impact of an AFCS malfunction that results in a sudden destabilization of the helicopter. As noted above, the certification standards for AFCS were developed for flight in IMC, in

which the loss of piloting assistance may become critical and which imposes higher system reliability/redundancy. Under VMC, however, the need for pilot assistance becomes less critical when the pilot has sufficient visual cues.

Consequently, a thorough assessment of failure modes should be done in the context of VMC and IMC, differentiating the operational implications of operating in each environment. In this context, equipment requirements for VFR operations should also be considered, as they may pertain to AFCS integration and failure modes. For example, Part 91 does not require an aircraft to have an attitude indicator. Consequently, it may make little sense to integrate an AFCS (in the context of enhancing stability for VFR operations) without requiring the installation of an attitude indicator. For example, an AFCS malfunction that induces a sudden destabilization under night VFR in mountainous terrain has the potential to be catastrophic.

AFCS malfunctions include:

- **Actuator Failure:** Actuator failures manifest themselves in a number of ways, depending on the design and its integration into the flight control system. Examples include:
 - Flight control seizure – failure results in jamming of a flight control.
 - Flight control linkage failure – failure breaks the mechanical connection of a flight control.
 - Hardover – malfunction causes an actuator to make a full control throw (i.e., to its minimum or maximum static position) while moving at the maximum rate. For actuators having large control authority and a fast response rate, a hardover could create a control input that places the aircraft in an unrecoverable flight condition.
- **Sensor Failure:** Sensor failures may prevent the AFCS from performing one or more of its intended functions; may result in a degraded mode, in which AFCS effectiveness/performance is suboptimal; or may cause a hardover. Likewise, these failures can occur in sensors designed to monitor, rather than control, system performance. In this situation, the crew may not be made aware of subsequent or latent failures in the AFCS.
- **Common Mode Failure:** Common mode failures can occur in redundant systems when one or more items of similar (or common) hardware/software fail, degrade, or generate unreliable information consistent with one another.
- **High-Intensity Radiation Fields (HIRF) Qualification:** The effects of HIRF and lightning can have a significant impact on AFCS certification due to their potential to cause a catastrophic failure (such as a hardover). The corresponding certification requirements typically impose very stringent testing requirements at the aircraft and equipment levels. While system tradeoffs may be considered to reduce such requirements, this typically requires a significant sacrifice in system performance to reduce the severity of a malfunction, such that it is no longer considered to be catastrophic.

A number of design strategies may be utilized to mitigate AFCS failures. In all cases, the design should allow the pilot to recognize the failure and, if required, manually recover the aircraft without exceptional pilot skill, alertness, or strength. In many cases, a flight test may be required to substantiate

the effectiveness of the AFCS design, including the transition from a fully operational state to a failed or degraded mode.

- **System Robustness:** The AFCS can be designed with sufficient robustness, through reliability or redundancy, such that the probability of a failure must be extremely improbable (i.e., a catastrophic failure, for which FAA guidance material requires a failure probability of at least 1×10^{-9}).
- **Limited Control Authority and/or Actuator Rate:** In order to reduce the severity of a failure (e.g., reducing a catastrophic event to hazardous), the control authority and/or control rate of actuators may be reduced, such that a hardover is fully recoverable under all foreseen flight conditions.
- **Dual System Designs:** Dual SAS/AFCS systems implement multiple rate and attitude sensors with multiple processing channels to control two actuators per axis. With this architecture, failure of a single system, actuator, or sensor will not result in total loss of stability augmentation. Additionally, the aircraft response to actuator hardovers is less severe in such cases, since the second fully operational system will counteract the erroneous input to the flight control system.
- **System Monitoring:** Monitoring of the AFCS system architecture, including all internal (integral) components as well as external sensors that provide inputs to the AFCS, may be considered to mitigate the impact of system or sensor failures. Multisensor comparison can be used to ensure improved monitoring, particularly for common mode failures, when multiple, nonidentical sensors are implemented.
- **Crew Alerting:** Crew alerting often plays a vital role in any design, particularly for those operations in which the pilot may be focusing attention outside the aircraft. The design of such alerts must therefore consider means that reliably alert the pilot of a failure or degraded condition. Crew alerting may be accomplished through visual annunciators, aural signals (tones or voice), and/or tactile cues (stick or seat shaker).

8. Technology

Advances in technology are accelerating at a pace that holds great promise to safely advance the integration of AFCS, avionics, and displays. For example, the development of the wide area augmentation system (WAAS) greatly extended the capabilities of GPS, enabling precision approach performance from satellite-based navigation. Similarly, the advent of micro-electromechanical systems (MEMS) subsequently resulted in the integration of this technology into attitude and heading reference system (AHRS) and attitude indicators, replacing heavier (and often less-reliable) mechanical gyros that were driven electrically or by a vacuum pump. In such cases, however, the new technology requires an understanding of the underlying physics, including how it works, its failure modes, and its interface requirements. Rather than focusing on individual technologies, a more pragmatic approach may entail globally addressing the capabilities that encompass these topics.

Additionally, as an applicant develops a new technology, ***it should be assumed that the applicant, rather than the FAA, will be the subject matter expert on the topic.*** Consequently, an applicant should

be prepared to develop and propose new means of compliance to the FAA, demonstrating the new technology to meet the intent of the certification requirements. Since the airworthiness requirements of Part 27/29 are generally agnostic to technology or design features, the focus should be on educating the FAA about the new technology's safety and reliability.

Further, the use of dissimilar technologies that provide similar functionality may show promise in the certification of new designs. For example, such technologies could be used to provide redundancy, enhance reliability, or improve monitoring while also providing low-cost, lightweight solutions.

As an example, the first integration of MEMS technology in attitude indicators was found to be sufficient for VFR operations. The FAA subsequently found potential safety issues for their use under IFR, requiring a new means of compliance to ensure that system integration and testing were adequately demonstrated for safe system performance. Since many new technologies (such as MEMS) have origins outside of the aerospace industry, thorough system analysis is essential to ensure the system performance and safety are adequate for aviation application.

The primary risk associated with SAS or autopilot failures in a VFR environment concerns malfunctions (such as hardovers) that result in large amplitude deviations or oscillations. Such malfunctions may be mitigated or otherwise reduced in severity in one of several ways. For example, a design may use similar, redundant systems, in which one system (designated as primary) actively controls the AFCS, while the other (secondary) systems passively monitor the primary system and, in case of system degradation or failure, take over active control. Alternatively, multiple systems may be integrated that have sufficiently dissimilar operational characteristics such that none of the systems will exhibit the same anomalous behavior at the same time and for the same minimum duration.

If the same technology is used in those redundant systems, high confidence must be put in all contributors of the subsystem. This need for confidence results from the increasing complexity of the electronics components that make up each subsystem. For example, components traditionally considered as complex (such as microcontrollers) are commonly used in elementary sensors and power supply converters, while high-performance processors (including multicore) may utilize several levels of cache memory and shared resources. However, the remarkable performance gains (and, equally important, the associated reliability) of systems integrating these complex components can be extremely difficult to prove in demonstrating compliance with existing certification requirements.

Alternatively, subsystems involving dissimilar electronic components or technologies are inherently unlikely to malfunction in the same manner. Consequently, the lack of common mode failures does not require the same high level of confidence as redundant but identical subsystems. If any of the high-performance, complex electronics components in one lane fails, the other lane(s) will not simultaneously exhibit the same failure. Rather, only those common sources of a malfunction, such as common control laws or environmental influences (e.g., HIRF, EMI, lightning), must be considered. Nevertheless, traditional aeronautical design practices have proved sufficient to mitigate common mode failures in software development and ensure that hardware designs are robust against environmental influences.

Consequently, the approval of the AFCS solutions, especially for simple SAS or low-complexity autopilot systems, should not impose today's common, high-end standard intended to cover redundant yet

identical lanes. Rather, a graduated set of standards could be utilized as a function of the amount of dissimilarity between the redundant lanes.

9. Certification Challenges and Alternatives

The process to certify a new AFCS system is complex, labor-intensive, expensive, and time-consuming. The process can take years, in part, due to the assumption that these systems were meant to be integrated with other critical systems to be certified for IFR operations. For example, the certification process might entail significant software development or ground/flight tests to verify that AFCS performance and failure modes were demonstrated to be safe. Additionally, the FAA has generally imposed a special condition for most AFCS installations since §27.1309 did not envision electronic systems with greater than major failure classifications for installation on a normal-category VFR rotorcraft.

9.1 Performance-Based Standards

More recently, Part 23 underwent a significant rewrite that resulted in performance-based requirements, which may show great promise in their applicability to the certification of AFCS rotorcraft. To date, however, such performance-based standards have not been established for Part 27 or 29. Further, under today's political climate, it is doubtful that sweeping changes to the rotorcraft airworthiness standards could be achieved without significant time and collaboration between the FAA and industry. Consequently, other approaches to certification may prove more meaningful to pursue. For example, while it may be very difficult to amend Part 27 to incorporate performance-based standards, it may be easier to capture such standards through new means of compliance (MoC). Such MoC could initially be proposed through the use of generic-issue papers until such time that the FAA could adopt their acceptance into Advisory Circulars (ACs) 27-1 and 29-2.

Similarly, performance-based standards could be captured through industry standards, established, for example, through SAE or RTCA. The FAA frequently uses such industry standards already to support the certification of AFCS, such as:

- RTCA DO-160, *Environmental Conditions and Test Procedures for Airborne Equipment*
- RTCA DO-178C, *Software Considerations in Airborne Systems and Equipment Certification*
- RTCA DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*

9.2 Nonrequired Safety-Enhancing Equipment

In 2016, the FAA launched another initiative to measurably enhance safety by encouraging greater use of nonrequired safety-enhancing equipment (NORSEE). Common equipment that may be approved as NORSEE includes avionics, electronic instruments, or displays that increase situational awareness, provide additional information beyond that of primary aircraft systems, provide independent alert indications, or provide additional occupant safety protection. The FAA formalized its NORSEE guidance in Policy Statement (PS) AIR-21.8-1602, which differentiates NORSEE as a special class of equipment that can enhance safety in order to accommodate and encourage the installation of new-technology safety enhancements.

It may be difficult to classify an AFCS as NORSEE. Nevertheless, other systems associated with the installation that provide additional redundancy, situational awareness, or alerting may well qualify. Consequently, greater use of the NORSEE policy may prove beneficial, not only for new rotorcraft with modern avionics systems but also as retrofit solutions for legacy VFR Part 27 helicopters.

NOTE: The NORSEE policy has not been adopted outside the FAA and might not be acceptable to other aviation authorities, such as EASA or TCCA.

9.3 Safety Continuum

As a follow-on activity to NORSEE, the FAA subsequently published PS-ASW-27-15, *Safety Continuum for Part 27 Normal Category Rotorcraft Systems and Equipment*. The new policy recognizes the advancements in rotorcraft system and equipment technology and their potential to enhance rotorcraft safety. Given the accelerated pace of technology development, the safety continuum recognizes a graduated scale for compliance with certification standards and their associated guidance material. The FAA's intent in the implementation of this policy is to encourage rotorcraft manufacturers, modifiers, owners, and operators to install systems and equipment that may enhance rotorcraft safety.

The *Safety Continuum* establishes four classes of Part 27 rotorcraft and associated development assurance levels (DAL), which are consistent with SAE ARP 4754 and ARP 4761. Through this approach, the *Safety Continuum* provides for a tiered means of compliance for systems and equipment, which in some cases reduces the probability requirements and DAL for some installations. For example, the DAL requirements for a single-, reciprocating-engine rotorcraft may be less stringent than those required for a twin-engine, turbine rotorcraft. In this light, the *Safety Continuum* may have significant applicability with respect to the certification of VFR autopilot systems.

As noted above, the HIRF qualification of AFCS systems has historically imposed significant test requirements. Consequently, some installations may sacrifice performance to mitigate the potential for a catastrophic event (such as a hardover). Further dialogue with the FAA is warranted to investigate whether the *Safety Continuum* may be extended to include HIRF and lightning effects, as has been done with Part 23 aircraft under PS-ACE-23-10, *HIRF/Lightning Test Levels and Compliance Methods for Part 23 Class I, II, and III Airplanes*. The intent of this policy is to define an alternate means of demonstrating compliance with Level A systems for HIRF and indirect lightning effects without the need to perform full airplane tests.

NOTE: The *Safety Continuum* policy has not been adopted outside the FAA and might not be acceptable to other aviation authorities, such as EASA or TCCA.

10. State of the Market

Given the pace of research, development, testing, and fielding of traditional and remotely piloted airframes and their supporting hardware and software systems, an exhaustive list representing the current state of the market is impossible to produce. The systems described below, however, offer a representation of current airframes, systems, and solutions for industry consideration.

10.1 Rotary-Wing Airframe Original Equipment Manufacturer (OEM) Solutions

- Bell: Bell currently offers certified Bell kits supporting 2-axis VFR and 3-axis VFR/IFR solutions for the 407GX/GXi. The 505 is offered with a third-party federated solution from Genesys.
- Leonardo: The TH-119 is offered with a third-party federated solution from Genesys.
- Robinson Helicopter Company, Inc.: Robinson currently offers a 2-axis Genesys SAS/Autopilot system with Robinson-specific features as an option on new R44 and R66 aircraft. The system is also available as a field retrofit on all R44 models. Additional systems and functionality are in the research and development phase; however, reducing costs is key to increasing adoption. Robinson is also considering options for IFR certification as a long-term goal.
- Airbus: Since the integration of the analog autopilot (first certified during the 1980s and 1990s), Airbus has not integrated any other single-engine rotorcraft autopilot systems. Further, the OEM has focused its AFCS integration into a multiengine platform due to the complexity and weight issues discussed above. More recently, Airbus has partnered with third-party AFCS manufacturers (such as Genesys and Garmin) to install their AFCS through an STC. Nevertheless, very few H125 aircraft (the most-popular single-engine Airbus platform) are equipped today with autopilots, as operators frequently criticize the additional weight of an AFCS, where even as little as 10 kg may be considered a no-go from an operational perspective.

10.2 Third-Party Solutions: Supplemental Type Certificate (STC) Retrofit Systems

- Genesys: HeliSAS 2-axis and 3-axis autopilot available in multiple aircraft
- Thales: Compact Autopilot System (CAPS)
- Garmin: GFC-600H—recently certified in the H125
- SAFRAN: Formerly SFIM helicopter AFCS

10.3 Emerging Solutions for Consideration

A. Special Class of Aircraft Certification

On September 18, 2020, the FAA published a new policy regarding the type certification of certain unmanned aircraft systems (UAS) as a special class of aircraft under 14 CFR Part 21 (Docket No. FAA-2019-1038). Part 107 sets forth rules for the operation of small UAS (i.e., those weighing less than 55 lbs.), which do not require FAA airworthiness certification. For any UAS that weighs over 55 pounds, or for a small UAS that will be operated under CFR Part 91 or 135, the FAA will require the UAS to receive an airworthiness certification, a waiver, or an exemption. The FAA appears to be steering operators of some UAS toward a type certification as a special class of aircraft under §21.17(b). The policy appears to be geared for UAS operations in which no occupants are on board, particularly those used for package delivery.

However, the FAA states in its policy that any occupant-carrying UAS should be certificated under the same process as manned aircraft and can only be certified as a special class of aircraft if no occupants are on board. Also, an optionally piloted aircraft (OPA) is considered a manned aircraft by the FAA for certification purposes and is beyond the scope of consideration for special-class certification.

Type certification for UAS carrying occupants (UAM vehicles, for instance) will be addressed by future FAA activity, either by policy or rulemaking.

B. Integration of UAS/UAM/eVTOL Stabilization Solutions

One of H-SE 70's mandates is to emphasize new and retrofit configurations not currently supported by SAS/autopilot solutions. In the future, fully automated, stabilized UAS/UAM and eVTOL aircraft will rely on inexpensive and redundant COTS equipment or systems to provide SAS/autopilot functions. Finding easier certification paths to adopt such COTS into Part 27 and 29 certification procedures where possible is a big part of H-SE 70's Output 2 and Section 5.0.

The integration of autonomous stabilization, navigation, and collision avoidance systems being developed for UAS/UAM/eVTOL aircraft can save lives in the manned helicopter community. A USHST H-SE 90 report, *Identifying How UAS/OPA Can Reduce Fatal Accidents in High Risk Manned Helicopter Operations*, considers fatalities in specific flight regimes in which helicopters have traditionally operated at very low levels, in all types of environmental conditions, and in which pilots are often susceptible to boredom, complacency, and distraction. In those accidents with fatalities, it was observed that a high potential for fatal accidents could possibly be alleviated by doing something different. An obvious solution is to integrate autonomous stabilization, navigation, and collision avoidance systems currently available to UAS.

C. Current UAS Industry Technology Solutions

- First-person forward and multidirectional simultaneous view
- Automatic takeoff and landing
- Self-leveling in flight or at hover
- Altitude hold
- Hover/position hold
- Autonomous and semi-autonomous flight with simultaneous data capture in 360 degrees relevant to the flight path
- Headless mode: Pitch control relative to the position of the pilot rather than relative to the vehicle's axes
- Terrain following: maintaining constant agl
- Automatic roll and yaw control
- GPS waypoint navigation with mapping
- Geotagging of collected data
- Georeferenced orthomosaics
- 3-dimensional point clouds
- 3-dimensional models
- Digital surface modeling
- Multispectral and hyperspectral imagery
- LiDAR imagery
- Infrared imagery (also referred to as thermal imaging)
- Normalized difference vegetation index (NDVI) imagery
- Automatic logging of all flight data parameters
- Failsafe: automatic landing or return-to-home

- *Omnidirectional collision avoidance: forward, rearward, sideward, and downward

*This feature, using any of the following or a combination of all (cameras, lasers, and short- and long-range radar), is nearly standard equipment on many production automobiles today. The feature goes by many different names (forward obstruction warning, smart city brake support, collision mitigation, forward collision alert/warning, intelligent brake assist, DISTRONIC Plus, presafe brake, EyeSight, etc.) but is essentially an anticollision system.

11. Conclusions

Our vision is to provide a significant reduction in rotorcraft LoC-I accidents, particularly fatal accidents following UIMC/IIMC events, by promoting the integration of advanced flight control systems and new technologies.

While a wide variety of SAS/AFCS options exist, their complexity, cost, and weight—and their associated certification requirements—can be significant and have been prohibitive for integration into Part 27 aircraft. The advent of new avionics and electronics, which have been successfully integrated into unmanned platforms, shows great potential in providing a significant safety return on investment in rotorcraft.

In particular, the integration of a full-time SAS, working in the background without pilot action, would provide full-time helicopter stability and a significant reduction in pilot workload. Such a system could become the standard to significantly enhance safety in a VFR environment while serving as the baseline for more-sophisticated AFCS designs that could be implemented across all helicopter operations, including VFR and IFR. In short, such SAS solutions might provide a low-cost, lightweight solution that could be easily integrated into Part 27 rotorcraft, providing a high safety return on investment.

12. Recommendations

- A. Expand and formalize industry and authority collaboration (e.g., FAA Aviation Rulemaking Advisory Committee, US Helicopter Safety Team, etc.).
- B. Establish VFR certification criteria for AFCS and SAS, focusing on the basic AFCS modes detailed above, designed for use in VMC but that may also provide substantial safety benefits when short-term degraded visual conditions may exist, such as IIMC.
- C. Develop and utilize performance-based standards (PBS), applying industry standards and aerospace recommended practices, such as those developed by RTCA and SAE.
 - (1) Establish corresponding means of compliance that are consistent with new technology (if applicable)
 - (2) Develop PBS consistent with VFR operations (day and night)
 - (3) Develop PBS that consider the certification of SAS for IFR operations.
- D. Develop new means of compliance that:
 - (1) Are consistent with FAA NORSEE and *Safety Continuum* policies

- (2) Establish guidelines that provide for the use of redundant, dissimilar technologies without mandating existing reliability requirements used today for redundant, similar systems.
- E. Review existing TSOs associated with avionics, displays, and AFCS for obsolescence and, when applicable, update the TSOs to reflect new PBS.
- F. Partner with AAM and UAS system developers to migrate and integrate new technologies into rotorcraft, based on their certification successes.
- G. Engage with trade associations, insurance providers, and Congress to advocate the incorporation of new safety-enhancing technology.
- H. Consider integration of any relevant data from other successful Part 23 certification projects.
- I. Review feedback and recommendations being developed by the General Aviation Manufacturers Association (and other aviation trade associations) regarding the implementation of the newly revised 14 CFR Part 23 standards (Amendment 64).

13. Annex A: Advanced Flight Control Systems

AFCS systems are commonly composed of several subsystems, each providing one or more basic functions. The integration of several subsystems collectively provides the AFCS with additional functionality and robustness. This section details the most basic functions and their traditional implementation.

A.1 Trim

Basic to any AFCS is a *trim hold* system, which can be implemented in several ways. The most basic form of retaining flight control position is provided through friction settings, but this may severely limit the integration of any additional AFCS subsystems, such as SAS or series actuators. Additionally, a *force gradient* trim system is typically required to comply with Part 27, Appendix A, requirements, so such systems are typically basic to all AFCS.

The term *force gradient* refers to the amount of force that must be applied as the pilot moves a flight control away from its *trimmed* control position. In other words, the larger the displacement a pilot makes away from the trim flight control position, the greater the force required to move the flight control further. The force is intended to automatically return the control to the original *trim* position without pilot input but be such that the pilot can easily override it in order to perform short-term maneuvers away from trim. For example, if the aircraft is trimmed for level flight, the pilot can initiate a turn to a new heading or to avoid a bird; when he releases the flight controls, the trim system will return the flight controls back to an *in trim* condition for level flight.

Typical force trim systems apply force using a system of springs and motors, a variable electromotive force, or similar actuation devices. Typical force trim systems also allow the pilot to rapidly set a new trim control position through a trim-release mechanism (referred to as force trim release) or to slowly change the trim position by beeping a trim motor, which adjusts the flight controls to a new trim position.

A.2 Stability Augmentation

Perhaps the biggest factor that affects cost, complexity, performance, safety design, and certification issues is how to provide stability augmentation. There are chiefly two ways this can be done: series actuation or parallel actuation. Both have benefits and challenges.

- **Series Actuation:** Series actuation, as the name suggests, works in series with the pilot's flight control inputs, introducing high-rate and relatively small displacement inputs (5%-10%) into the control system (see figure 1). The pilot, for the most part, is unaware of the transparent help provided by the SAS, which works at all times to provide smoother and more coordinated flight while providing rapid corrections for turbulence and similar disturbances, often more quickly than a pilot is capable of performing. Series actuation has the ability to improve the basic handling characteristics of the aircraft, making it seem generally better behaved and easier to fly. Systems using series actuators will typically also utilize parallel actuators to provide trim and other autopilot functions.
- **Parallel Actuation:** Parallel actuators typically have 100% control authority yet operate at slower rates than series actuators. Systems that employ parallel actuation for SAS and

autopilot functions provide their control inputs directly to the flight controls along with the pilot. They apply control forces to move the control sticks, even when the pilot is actively flying the aircraft. The actuator design must allow the pilot to overpower any inputs applied by the parallel actuator with relative ease. When operating as a SAS, with the pilot on the controls, it is like having a second pilot on the controls, nudging them with forces and inputs to help make the required corrections. In this actuation scheme, when flying with SAS, the pilot can feel the SAS system control inputs and must operate with a soft enough grip on the controls to allow the SAS to move the controls to do its job.

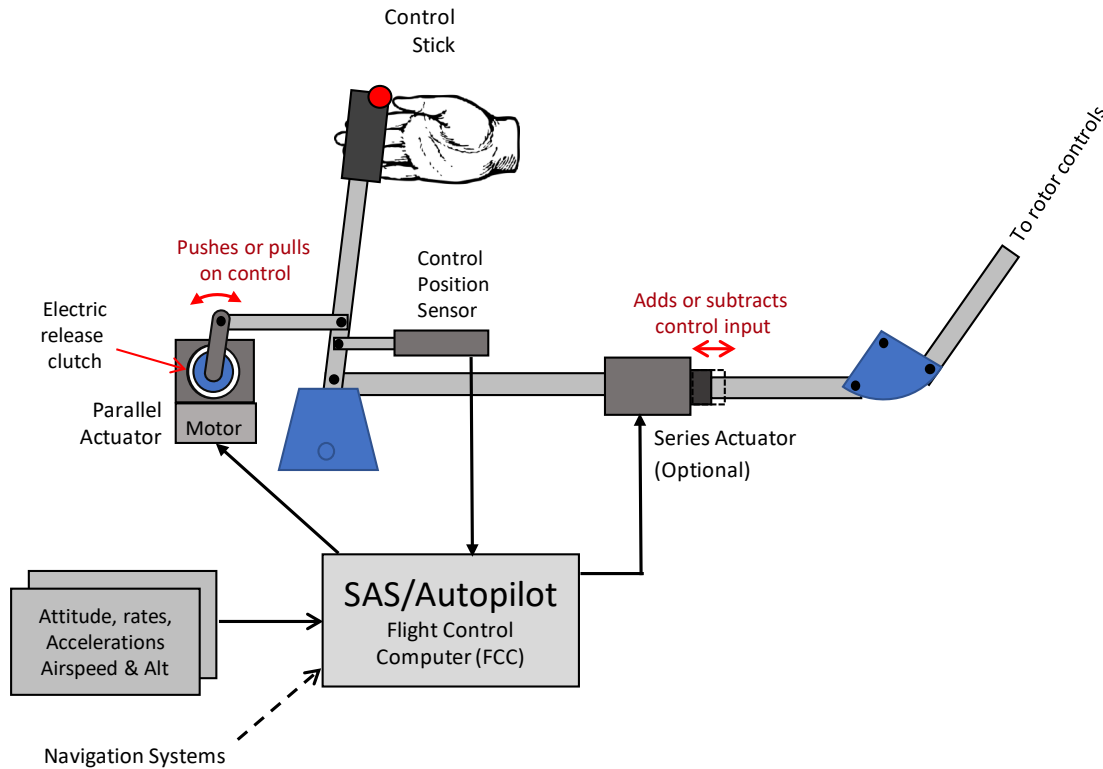


Figure 1. Traditional Single-Control Axis SAS/Autopilot Architecture

Systems that use parallel actuation only are generally lower cost and easier to retrofit on existing aircraft than systems that include series actuators. A parallel-only design can provide SAS, force trim, and autopilot functions within a single actuator per control axis. However, there are generally performance compromises and increased difficulty in certification for parallel-only designs.

Systems that utilize both parallel and series activation generally have a higher level of performance, features, and capabilities typically found in larger rotorcraft but at the expense of complexity, weight, and cost. The added complexity also adds to the certification burden.

- **Dual System Designs:** Dual SAS/AFCS systems implement multiple rate and attitude sensors with multiple processing channels to control two actuators per axis. With this architecture, failure of a single system, actuator, or sensor will not result in total loss of stability augmentation. Additionally, aircraft response to actuator hardovers is less severe, since the

second, fully operational system will counteract the erroneous input to the flight control system.

- **Series/Parallel Designs:** Series/parallel systems consist of high-rate limited-authority series actuators and low-rate full-authority parallel actuators. This architecture allows the system to insert fast control inputs required for rate damping and short-term stability, as well as large inputs for attitude retention, upper modes, and series actuator centering. The combination of high-rate limited-authority and low-rate full-authority actuators provides the desired stability and control while limiting the aircraft response to system malfunctions and actuator hardovers and runaways.

14. Annex B: References

1. [Update](#) on helicopter safety enhancement for technology support to improve stability augmentation and autopilot systems (H-SE 70)
2. US Helicopter Safety Team (USHST) [Report: Helicopter Safety Enhancements](#) *Loss of Control – In flight, Unintended Flight in IMC, and Low-Altitude Operations*, October 3, 2017
3. NTSB Aviation Accident Database & Synopses:
https://www.nts.gov/_layouts/ntsb.aviation/index.aspx
4. [14 Code of Federal Regulations, Part 27, Appendix B](#), *Airworthiness Standards: Normal Category Aircraft, Airworthiness Criteria for Helicopter Instrument Flight*
5. [FAA Advisory Circular, AC 27-1B](#), *Certification of Normal Category Rotorcraft*
6. [RTCA DO-160](#), *Environmental Conditions and Test Procedures for Airborne Equipment*
7. [RTCA DO-178C](#), *Software Considerations in Airborne Systems and Equipment Certification*
8. [RTCA DO-254](#), *Design Assurance Guidance for Airborne Electronic Hardware*

15. Annex C: Acronyms

The following is a list of acronyms used in this document.

Table 2: Acronym List

Acronym	Description
AAM	FAA Offices of Aerospace Medicine
AC	Advisory Circular
AFCS	Automatic Flight Control System
AGL	Above Ground Level
AHRS	Attitude and Heading Reference System
ALT	Altitude hold, in the context of a mode of SAS / Autopilot system engagement
ARP	Aerospace Recommended Practice
ATC	Air Traffic Control
CAPS	Compact Autopilot System
CAR	Civil Aviation Regulations
CAST	Commercial Aviation Safety Team
COTS	Commercial Off-The-Shelf
DAL	Development Assurance Levels
EASA	European Union Aviation Safety Agency
EMI	Electro-Magnetic Interference
eVTOL	Electric Vertical Takeoff and Landing
FAA	Federal Aviation Administration
FADEC	Full Authority Digital Engine Control
GAJSC	General Aviation Joint Steering Committee
GPS	Global Positioning System
GS	GlideSlope, in the context of an instrument approach procedure or system
HIRF	High Intensity Radiation Fields
H-SE	Helicopter Safety Enhancement
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IIMC	Inadvertent Instrument Meteorological Conditions. Also see: UIMC
LALT	Low Altitude operations
LIDAR	Light Detection and Ranging
LOC	Localizer, in the context of an instrument approach procedure or system
LoC / LoC-I	Loss of Control / Loss of Control In flight
LPV	Localizer Performance with Vertical guidance
MEMS	Micro Electro Mechanical Systems

Acronym	Description
MoC	Means of Compliance
MSL	Mean Sea Level
NAV	Navigation, in the context of a mode of SAS / Autopilot system engagement
NDVI	Normalized Difference Vegetative Index: imagery technology associated with UAS
NORSEE	Non-Required Safety Enhancing Equipment
NTSB	National Transportation Safety Board
OEI	One Engine Inoperative
OEM	Original Equipment Manufacturer
OPA	Optionally Piloted Aircraft
PBS	Performance Based Standards
RRRP	Rotorcraft Regulatory Review Program
RTCA	Radio Technical Commission for Aeronautics
SAE	SAE International, a global entity that develops engineering standards for various industries.
SAFRAN	International technology group with aerospace, defense, and security as its core businesses
SAS	Stability Augmentation System
SAT	Safety Analysis Team
SFAR	Special Federal Aviation Regulation
SOW	Statement of Work
STC	Supplemental Type Certificate
SVFR	Special Visual Flight Rules
TCCA	Transport Canada Civil Aviation
TSO	Technical Standard Orders
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UIMC	Unintended Flight into Instrument Meteorological Conditions. Also, see IIMC
USHST	United States Helicopter Safety Team
VMC	Visual Meteorological Conditions
V_{MINI}	Instrument Flight Minimum Speed
V_{NE}	Velocity to Never Exceed
V_Y	Best Rate of Climb Speed
VOR	VHF Omnidirectional Range / Radio
VORTAC	VHF Omnidirectional Range / Tactical Aircraft Control
WAAS	Wide Area Augmentation System

16. Annex D: NTSB Accident Reports Supporting this Safety Enhancement

Table 3: NTSB Accident Reports Supporting H-SE 70

Ref	Accident Report No.	Accident Summary
1	WPR10FA055	2009 Doyle, CA: Loss of control in flight; 3 Fatal
2	CEN13FA003	2012 Intracoastal City, LA: VFR encounter with IMC; 1 Fatal
3	CEN13FA010	2012 Blanco, TX: Loss of control in flight; 3 Fatal
4	WPR13FA080	2013 Delano, CA: Loss of visual reference; 1 Fatal
5	ERA09FA537	2009 Georgetown SC: VFR encounter with IMC; 3 Fatal
6	ERA13FA273	2013 Manchester, KY: Loss of control in flight; 3 Fatal
7	CEN11FA468	2011 Rising Sun, In: Loss of visual reference; 1 Fatal
8	WPR13GA128	2013 Eureka, NV; Low altitude operation; 1 Fatal

Note: A summary of the NTSB accident report is provided in the pages that follow. To view a copy of the NTSB accident report docket, click on the accident number link included in each summary report below.

NTSB Report #1

Location:	Doyle, CA	Accident Number:	WPR10FA055
Date & Time:	11/14/2009, 0201 PST	Registration:	N5793P
Aircraft:	AEROSPATIALE AS350BA	Aircraft Damage:	Substantial
Defining Event:	Loss of control in flight	Injuries:	3 Fatal
Flight Conducted Under:	Part 91: General Aviation - Positioning - Air Medical (Unspecified)		

Analysis

Ten minutes after dropping off a patient at the local hospital and while returning to home base in dark night conditions, the flight crew made a routine position report. About 8 minutes later, the flight crew transmitted that the helicopter was going down.

Radar data indicated that after departure from the hospital, the helicopter initiated a climb from about 4,500 feet mean sea level (MSL) and established a northwesterly course. In the vicinity of the accident site, the target indicated a climbing turn to the northeast followed by a turn to the southwest, and then a climbing turn back to the northeast. The last two targets indicated a turn to the right. The last recorded altitude was at 10,200 feet MSL.

On-site documentation of the wreckage suggested that the helicopter was in a nose-low attitude and about a 90-degree bank angle when it contacted the ground.

A post-accident examination of the airframe and engine revealed no evidence of mechanical malfunctions or failures that would have precluded normal operation.

A study of the weather conditions in the vicinity of the accident site indicated clouds were present with tops reaching about 13,000 feet MSL. Light clear icing was present with the potential for moderate clear icing in or near clouds. Visibility was at or greater than 10 statute miles.

Given the helicopter's flight path shortly before the accident, it is likely that the pilot was maneuvering to avoid clouds and became disorientated in the dark night conditions, which resulted in a loss of helicopter control.

Probable Cause and Findings

The NTSB determines the probable cause(s) of this accident to be: The pilot became spatially disoriented while maneuvering on a dark night, which resulted in a loss of helicopter control.

NTSB Report #2

Location:	Intracoastal City, LA	Accident Number:	CEN13FA003
Date & Time:	10/05/2012, 0758 CDT	Registration:	N406AL
Aircraft:	BELL 407	Aircraft Damage:	Substantial
Defining Event:	VFR encounter with IMC	Injuries:	1 Fatal
Flight Conducted Under:	Part 91: General Aviation - Other Work Use		

Analysis

According to the operator, the pilot was performing a local post-maintenance flight following a routine phase check that had been completed the previous evening. Several witnesses reported seeing the helicopter start up and enter a low altitude hover before it hover-taxed toward the runway. One witness reported that she saw the helicopter depart on the runway heading and disappear into fog or a low cloud ceiling. Another witness, who also was a pilot employed by the operator, reported that there was mist, fog, and a low cloud ceiling when the helicopter departed.

Recovered flight data indicated that, about 20 seconds after takeoff, the helicopter reached a maximum altitude of 255 feet and ground speed of 51 knots while still on the runway heading. The helicopter then entered a left descending turn, during which, it reached a maximum bank angle of 38 degrees to the left and a 20-degree nose-down pitch angle. The helicopter also achieved a 1,600 ft per minute descent during the turn. After turning about 200 degrees from the original departure heading, the helicopter descended into trees and terrain in a nose-low, left-skid-low attitude.

The post-accident examination of the helicopter revealed no evidence of a preimpact failure or malfunction that would have precluded normal operation. Additionally, the engine exhibited damage consistent with it operating at the time of impact. The witness accounts of the helicopter climbing into a low cloud ceiling during initial climb and the subsequent descending left turn shown by the recovered flight data were consistent with the pilot inadvertently encountering instrument meteorological conditions and then attempting a course reversal. Additionally, the helicopter's descent rate and pitch and bank angles during the course reversal were consistent with the pilot lacking a discernible horizon or ground reference to maintain control of the helicopter. Although the helicopter was equipped with basic attitude instrumentation and avionics, it was not certified for flight under instrument flight rules (IFR). Additionally, although he held an instrument rating for helicopters, the pilot was not current for IFR operations nor was it required for his employment as a pilot of helicopters limited to VFR operations.

Probable Cause and Findings

The NTSB determines the probable cause(s) of this accident to be: The pilot's decision to attempt a local flight in marginal visual meteorological conditions and his subsequent loss of control following an inadvertent encounter with instrument meteorological conditions shortly after takeoff.

NTSB Report #3

Location:	Blanco, TX	Accident Number:	CEN13FA010
Date & Time:	10/11/2012, 1958 CDT	Registration:	N474FA
Aircraft:	ROBINSON HELICOPTER COMPANY	Aircraft Damage:	Substantial
Defining Event:	Loss of control in flight	Injuries:	3 Fatal
Flight Conducted Under:	Part 91: General Aviation - Other Work Use		

Analysis

According to track data recovered from a handheld GPS receiver found in the wreckage, the helicopter was on the final leg of a cross-country flight that had originated earlier in the day. According to fueling documentation, the helicopter was refueled, and the flight departed and proceeded on a southeast course toward the intended destination. According to the plotted GPS data, while enroute, about 600 feet above ground level (agl), the helicopter entered a descending left turn to an east-northeast course. About 30 seconds later, after descending about 100 feet, the helicopter entered a climb while on a northeast heading. During the climb, the helicopter's groundspeed decreased from 73 knots to 27 knots. The final GPS data point, recorded about 1 minute after the initial turn from the intended course, showed the helicopter about 800 feet agl at 27 knots groundspeed and about 0.2 mile north-northwest of the accident site. The helicopter wreckage was located in a sparsely populated area with hilly terrain. The debris path was orientated on a south-southeast heading, and the length and distribution of the debris path were consistent with the helicopter impacting rising terrain at cruise speed. Post-accident examination of the helicopter revealed no evidence of a pre-impact failure or malfunction.

A post-accident review of meteorological data established that marginal visual flight rules (VFR) conditions likely existed in the vicinity of the accident site at the time of the accident. The weather data supported increasing low-level cloud development and scattered light rain showers. No strong outflow winds or severe storm signatures were associated with the observed rain showers. The accident flight was conducted in dark nighttime conditions with minimal illumination from ground light sources. The helicopter's flight path during the last minute of GPS data was consistent with the pilot becoming spatially disoriented due to the lack of a discernible horizon that he could use to maintain control of the helicopter. Although the helicopter was equipped with basic attitude instrumentation and avionics, it was not certified for flight under instrument flight rules (IFR). Additionally, although the pilot held an instrument rating for helicopters, his IFR currency could not be verified.

According to FAA correspondence, about 5 months before the accident, the FAA had notified the pilot that he was ineligible to hold any class of medical certificate because of his multiple alcohol-related offenses. Although he had been advised multiple times of his ineligibility to hold a medical certificate, flight documentation established that the pilot continued to exercise the privileges of his commercial and flight instructor certificates. Toxicological test results for the pilot were negative for carbon monoxide, cyanide, ethanol, and all drugs and medications.

The helicopter operator reported that the accident occurred during an instructional flight; however, a review of available evidence did not support that the front-seat passenger was receiving flight instruction on the accident flight. According to FAA records, the front-seat passenger had never applied for a student pilot certificate or an aviation medical certificate. Additionally, a pilot logbook was not recovered during the investigation for the front-seat passenger. According to a business associate of both passengers, the front-seat passenger had coordinated the flight to attend a business appointment. According to photographs recovered from the front-seat passenger's mobile phone, on earlier flight legs, he had been seated in the left front seat. According to the helicopter manufacturer, the flying pilot typically would be seated in the right front seat, especially during initial flight instruction. Additionally, a review of the front-seat passenger's mobile phone established that he had been exchanging text messages with a business colleague in the minutes preceding the accident. Specifically, the final outgoing text message was sent about 26 seconds before the helicopter deviated from the direct course toward the intended destination. Therefore, it is unlikely that the passenger was operating the helicopter at the time of the accident.

Probable Cause and Findings

The NTSB determines the probable cause(s) of this accident to be: The pilot's loss of helicopter control as a result of spatial disorientation due to dark night conditions and marginal VFR weather conditions.

NTSB Report #4

Location:	Delano, CA	Accident Number:	WPR13FA080
Date & Time:	01/02/2013, 0615 PST	Registration:	N828AC
Aircraft:	BELL 206	Aircraft Damage:	Destroyed
Defining Event:	Loss of visual reference	Injuries:	1 Fatal
Flight Conducted Under: Part 91: General Aviation - Other Work Use			

Analysis

The accident helicopter was returning to the airport. Dark night visual meteorological conditions prevailed at the time with increasing fog. The pilot of a second helicopter, who was flying nearby and was in contact with the accident pilot, stated that, before the accident, he saw the accident helicopter make a right turn; he then asked the pilot if she was lost. The accident pilot responded that she thought she was. The second pilot told her to turn left toward the airport. Shortly after, the second pilot observed a fire on the ground and attempted to contact the accident pilot but received no reply. The accident helicopter crashed about 10 miles southeast of the destination airport. Post-accident documentation of the accident site revealed signatures indicative of a steep right turn while impacting vegetation and terrain. Examinations of the helicopter and engine revealed no evidence of preimpact mechanical malfunctions or failures that would have precluded normal operation. The dark night conditions, sparsely lit terrain, and accumulating fog reduced the visual cues available for the pilot to maintain orientation, and, under those conditions, the helicopter's external spotlights, which were on during the accident flight, could have further reduced or provided misleading visual cues. These conditions were conducive to the development of spatial disorientation.

Probable Cause and Findings

The NTSB determines the probable cause(s) of this accident to be: The pilot's failure to maintain helicopter control due to spatial disorientation while maneuvering in low visibility, dark night conditions.

NTSB Report #5

Location:	Georgetown, SC	Accident Number:	ERA09FA537
Date & Time:	09/25/2009, 2331 EDT	Registration:	N417AE
Aircraft:	EUROCOPTER AS-350	Aircraft Damage:	Destroyed
Defining Event:	VFR encounter with IMC	Injuries:	3 Fatal
Flight Conducted Under: Part 91: General Aviation - Other Work Use - Air Medical (Unspecified)			

Analysis

After conducting an interfacility patient transfer, the pilot refueled and then requested flight following services from air traffic control, departing in visual meteorological conditions (VMC) for the return flight to his base. During the return flight, the pilot encountered instrument meteorological conditions (IMC). A review of Sky Connect data for the accident flight revealed that the helicopter was cruising at varying altitudes and never reached a steady state cruise altitude for any significant period of time. The majority of the flight was flown at altitudes below 1,000 feet with the greater part of the last 8-minute segment of the flight being operated below 800 feet. (The lowest altitude recorded during the last cruise segment of flight was 627 feet.) Witnesses who observed the helicopter before the accident described it as flying about 1,000 feet above ground level (agl), with its searchlight turning on and off, in moderate to heavy rain. A subsequent loss of control occurred, and the helicopter impacted terrain about 1.92 nautical miles (nm) southwest of Georgetown County Airport (GGE).

Post-accident examination of the main wreckage revealed no evidence of any preimpact failures or malfunctions of the engine, drive train, main rotor, tail rotor, or structure of the helicopter. Additionally, there was no indication of an in-flight fire.

During the first legs of his flight, the pilot experienced and observed VMC conditions along his route. However, post-accident witness reports and in-flight statements from the accident pilot indicated that the weather in the area had deteriorated since his southbound flight 2 hours prior. According to Omniflight's Savannah, Georgia, base manager, who was also a pilot operating in the area on the night of the accident, the weather that night was deteriorating but was forecast to remain well above minimums for his flight from Savannah to Greenville, South Carolina, and then to the Medical University of South Carolina (MUSC) in Charleston. However, while he was refueling at the Greenville airport, the pilot of the accident helicopter contacted him by radio and advised him to double check the weather before returning to MUSC. The accident pilot stated that "bad thunderstorms" were in the GGE area and that he did not know if he would be able to return to his base that night. The Savannah base manager then advised the accident pilot that he could stay at the Charleston base that night. However, the accident pilot decided to return to his base at Conway-Horry County Airport (HYW), Conway, South Carolina.

Review of radar data and weather observations provided by the National Oceanic and Atmospheric Administration revealed that, after departing, the helicopter entered an area of convective activity and precipitation. The University Corporation for Atmospheric Research regional radar mosaic chart for 2333 also depicted a large area of echoes north of the frontal boundary, with several defined thunderstorms and rain showers extended over South Carolina and over the accident helicopter's flight route. Additionally, correlation of the radar data to the location of the accident site revealed that several defined cells surrounded the site at the time of the accident. The terminal aerodrome forecast (TAF) for Myrtle Beach International Airport, Myrtle Beach, South Carolina, which was located 29 nm northeast of the accident site, was issued about 1928 and indicated expected marginal visual flight rules conditions through 0100 on September 26. From 2000 through 2130, variable winds to 15 knots with visibility of 4 miles in thunderstorms, moderate rain, and a broken ceiling of 3,500 feet agl in cumulonimbus clouds were expected. From 2130 to 0100, the wind was expected to be from 040 degrees at 12 knots with a visibility of 6 miles in light rain showers and mist and a broken ceiling at 2,000 feet agl. About 2207, the National Weather Service issued an amended TAF that expected instrument flight rules (IFR) conditions to prevail during the period with a broken ceiling at 700 feet agl and light drizzle and mist after midnight.

The pilot had previously flown helicopters in IMC but was not current in instrument ratings at the time of the accident. The accident helicopter was not certificated for flight in IMC but had sufficient instrumentation to operate in the event of an inadvertent encounter with IMC. On the pilot's last Part 135 airman competency/proficiency check, which occurred on December 12, 2008, he satisfactorily demonstrated inadvertent IMC loss of control recovery.

Although the pilot encountered an area of deteriorating weather and IMC, this did not have to occur as the pilot did not have to enter the weather and could have returned to Charleston Air Force Base/International Airport or landed at an alternate location. The pilot, however, chose to enter the area of weather, despite the availability of safer options. Based on the pilot's statement to the Savannah-based pilot regarding bad thunderstorms in the area, he was aware of the weather and still chose to fly into it. In addition, the pilot's inability to maintain a steady state cruise altitude during the flight and the declining altitude throughout the flight likely reflected his attempt to stay below the cloud level. These cues should have indicated to the pilot that it was not safe to continue flight into IMC. This decision-making error played an important causal role in this accident.

In the absence of evidence indicating a mechanical malfunction, severe turbulence, or some other factor that would explain the accident pilot's apparent loss of control of the helicopter, spatial disorientation is a likely explanation, as it has contributed to many accidents involving loss of control. In many cases, loss of control follows a pilot's inappropriate control inputs resulting from confusion about the aircraft's attitude. Two major situational risk factors for spatial disorientation were present in this accident, including high workload and transitions between VMC and IMC that require shifting visual attention between external visual references and cockpit flight instruments. Attempts to continue visual flight into IMC are even more problematic for helicopter pilots than for pilots of fixed-wing aircraft because helicopters are inherently less stable and require near-continuous control inputs from the pilot. Helicopters, like the accident helicopter, that are not equipped for IFR flight and do not have control stabilization, or an autopilot impose high perceptual and motor demands on the pilot. This can make it very challenging for pilots to maintain stable flight by referring to flight instruments alone. When the accident pilot attempted to continue visual flight into IMC, he would have been subjected to a high workload to maintain control of the helicopter. The extent of the weather and the duration of the flight also suggest that the pilot's encounter with IMC was prolonged. This would have further complicated the pilot's workload and increased the potential for spatial disorientation resulting from hazardous illusions, thereby increasing the potential for inappropriate control input responses.

According to Omniflight's 135 Operations Manual, the pilot-in-command was responsible for obtaining weather information before beginning a series of flights. During interviews with National Transportation Safety Board (NTSB) investigators, Omniflight pilots indicated that, at the beginning of each shift, they would obtain weather information from a base computer and would advise the Omniflight Operational Control Center (OCC) of weather conditions in the operating area throughout the period of their flight. Before any launch, the OCC must approve the flight. If the OCC knew of adverse weather, it would contact the pilot to evaluate the weather. Based on launch approval and actual weather conditions encountered and reported by the pilot, the weather at takeoff and along the flight route was VMC. About 2242, an MUSC communications center specialist spoke with an Omniflight OCC operations coordinator and indicated that the helicopter would be returning to HYW as soon as the patient transfer was complete. The operations coordinator then advised the MUSC specialist that if the pilot called before takeoff, they would review the weather with him for his return flight. However, the pilot never called the OCC, and the OCC did not contact the pilot. While the OCC was not required to contact the pilot and review the weather, if the OCC had contacted the pilot before takeoff, the OCC could have advised the pilot about the adverse weather, given him the updated TAF information issued about 2207 with IMC, and noted the potential risks involved with the flight. On February 7, 2006, the NTSB issued Safety Recommendation A-06-14, which asked the Federal Aviation Administration (FAA) to "require emergency medical services operators to use formalized dispatch and flight-following procedures that include up-to-date weather information and assistance in flight risk assessment decisions." On February 18, 2010, based on the FAA's pending notice of proposed rulemaking concerning helicopter operations and pending timely issuance of a final rule mandating formalized dispatch and flight-following procedures that include up-to-date weather information and assistance in flight risk assessment decisions, the NTSB classified this recommendation "Open—Acceptable Response."

The accident helicopter was not equipped with an autopilot. On September 24, 2009, the NTSB issued Safety Recommendation A-09-96, which asked the FAA to “require helicopters that are used in emergency medical services transportation to be equipped with autopilots and that the pilots be trained to use the autopilot if a second pilot is not available.” On December 23, 2009, the FAA stated that it would conduct a study of the feasibility and safety consequences of requiring a second pilot or operable autopilot. On October 7, 2010, pending the NTSB’s review of the results of this study, Safety Recommendation A-09-96 was classified “Open—Acceptable Response.”

Probable Cause and Findings

The NTSB determines the probable cause(s) of this accident to be: The pilot’s decision to continue the visual flight rules flight into an area of instrument meteorological conditions, which resulted in the pilot’s spatial disorientation and a loss of control of the helicopter. Contributing to the accident was the inadequate oversight of the flight by Omniflight’s Operational Control Center.

NTSB Report #6

Location:	Manchester, KY	Accident Number:	ERA13FA273
Date & Time:	06/06/2013, 2315 EDT	Registration:	N114AE
Aircraft:	BELL HELICOPTER TEXTRON 206L-1	Aircraft Damage:	Destroyed
Defining Event:	Loss of control in flight	Injuries:	3 Fatal
Flight Conducted Under: Part 91: General Aviation - Positioning - Air Medical (Discretionary)			

Analysis

The air ambulance repositioning flight was en route to base following a patient transfer. Weather information forecast about 3 hours before the accident indicated a moist environment; however, visual conditions were anticipated around the time of the accident. An updated forecast was published about 10 minutes before the accident, and it indicated that fog or low stratus cloud development was possible and that visibility could decrease to near or below airport weather minimums in the early morning hours. Witness statements and the reported weather conditions indicated that patchy fog had developed near the helipad at the time of the accident and that visibility at the accident site was 1/4 mile; however, the specific visibility conditions encountered by the helicopter during its approach could not be determined. A witness reported seeing the helicopter “flying lower than normal” and then spinning before impact. Another witness reported seeing the helicopter in a nose-down attitude and then impact the ground.

The wreckage was located in a school parking lot, which was about 750 feet from the landing pad and at an elevation of about 900 feet mean sea level (msl). The wreckage distribution was consistent with an in-flight separation of the main rotor and tailboom. An examination of the helicopter airframe, engine, and related systems revealed no pre-impact anomalies that would have precluded normal operation. Both the main rotor assembly and tailboom separated in overload.

Review of GPS data showed the accident helicopter descending in three right circuits near the landing pad just before the accident. The final recorded data were in the immediate vicinity of the accident location and indicated an altitude of 1,437 feet msl. The maneuvering flight path of the helicopter before the accident was consistent with an attempt to avoid fog followed by a loss of control. Although the pilot was instrument rated, he had not logged recent instrument time. Further, although the pilot had recent training in night vision goggle usage and had night vision goggles available during the flight, it could not be determined if he was using them at the time of the accident. Given the reports of fog in the area and the accident circumstances, it is likely that the pilot entered instrument meteorological conditions during the approach to the helipad, which resulted in spatial disorientation and loss of control.

Probable Cause and Findings

The NTSB determines the probable cause(s) of this accident to be: The pilot’s loss of helicopter control due to spatial disorientation when he inadvertently encountered night, IMC, which resulted in the in-flight separation of the main rotor and tailboom.

NTSB Report #7

Click on the Accident Number below to review the NTSB's full accident docket for this occurrence.

Location:	Rising Sun, IN	Accident Number:	CEN11FA468
Date & Time:	07/09/2011, 0927 EDT	Registration:	N42333
Aircraft:	ROBINSON HELICOPTER COMPANY R44 II	Aircraft Damage:	Substantial
Defining Event:	Loss of visual reference	Injuries:	1 Fatal
Flight Conducted Under: Part 91: General Aviation - Personal			

Analysis

The non-instrument-rated pilot contacted approach control and requested clearance through class B airspace with visual flight rules (VFR) radar service to his destination. About 7 minutes later, the pilot reported that he needed to descend because he was "getting into too many clouds." The approach controller approved the VFR descent and instructed the pilot to maintain VFR at or below 2,000 feet. About 6 minutes later, radar data were lost. Recorded radar track data indicated that the helicopter was on a northwest heading and then turned west, that the helicopter's altitude varied between 1,100 to 1,300 feet above ground level, and that the helicopter appeared to be in a right turn before impact. The helicopter impacted trees near the top of a ridgeline located about 0.3 mile west of the Ohio River at an elevation of about 700 feet. The Cincinnati/Northern Kentucky International Airport, located about 13 nautical miles northeast of the accident site, reported 4 miles visibility, haze, and scattered clouds at 1,100 feet. Witnesses reported dense ground fog along the river and on the ridgeline near the accident site at the time of the accident. A post-accident examination of the airframe and engine revealed no evidence of mechanical malfunctions or failures that would have precluded normal operation. Based on the pilot's inexperience, the radar data, and the reduced visibility at the time of the accident, it is likely that the he experienced spatial disorientation, which led to his failure to maintain clearance from the terrain.

Probable Cause and Findings

The NTSB determines the probable cause(s) of this accident to be: The non-instrument-rated pilot's decision to continue the visual flight rules flight into IMC, which resulted in his spatial disorientation and failure to maintain clearance from terrain.

NTSB Report #8

Location:	Eureka, NV	Accident Number:	WPR13GA128
Date & Time:	02/18/2013, 1424 PST	Registration:	N20620
Aircraft:	BELL 206B	Aircraft Damage:	Substantial
Defining Event:	Low altitude operation	Injuries:	1 Fatal
Flight Conducted Under: Public Aircraft			

Analysis

The pilot was flying a helicopter as part of a Department of Interior (DOI) reseeding project when the helicopter struck the static line above a set of power transmission lines. Post-accident examination of the engine and airframe revealed no evidence of mechanical malfunctions or failures that would have precluded normal operation. The length and direction of the debris field was consistent with the helicopter traveling in the direction of, and at a rate of speed consistent with, a seed dispersal run.

The pilot was familiar with the area and was aware of the transmission lines, having performed a reconnaissance flight and flown over them multiple times during the previous flights that day. In the area of the accident site, the power lines began an ascent up an adjacent hill, with the static lines diverging such that they were about 40 feet higher than the power lines at the collision location. The static lines were of thinner gauge and could easily have been obscured by the surrounding hilly terrain. The lines were depicted on the relevant Federal Aviation Administration sectional chart. The helicopter was not equipped with a wire strike protection system nor was it required to be under the terms of the DOI contract. Neither the power nor static lines were equipped with visibility markers nor were they required to be due to their elevation above ground level.

The pilot had flown 40.5 hours over the last 5 days as part of the reseeding project, which was just short of the DOI contract maximum. A review his sleep history indicated that he received adequate rest the night before the accident. On the morning of the accident, he had flown 10 application runs in an area about 70 miles away. He took a lunch break about 3 hours before the accident, then flew 20 separate seed application runs and 10 reloads. His total flight time for that day was 6.6 hours. The low-level and “nap of the earth” flight operations required considerable concentration, most likely resulting in task-and/or work-related fatigue at the end of the day. By comparison, the United States Army recommends a maximum flight time of 8 hours per day or 37 hours per week, with a reduction of a factor of 1.3 to 1.6 for low-level and “nap of the earth” flying; thus the pilot would have exceeded their duty hour recommendations for each of the 5 days leading up to and including the accident day.

The pilot held an assisted special issuance second-class medical certificate based on a reported history of diabetes for which he was taking medication. His most recent medical examination revealed a new diagnosis for hypertension, as well as preexisting cataracts in both eyes, which exhibited no change since his last examination a year prior. In part due to the lack of an autopsy, the relevance of these findings, combined with his likely work-related fatigue, could not be determined.

Probable Cause and Findings

The NTSB determines the probable cause(s) of this accident to be: The pilot’s failure to maintain clearance from a wire while maneuvering during low-altitude operations. Contributing to the accident was task- and/or work-related fatigue.

17. Annex E: US Helicopter Safety Team

USHST

To learn more about the US Helicopter Safety Team, visit www.ushst.org. Site visitors can review and download an electronic copy of this report and others in the document repository. A summary of other USHST helicopter safety enhancements and related work is also available for review.

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