Maintaining Proficiency in Autorotations

Practice autorotations are a vital part of helicopter training … but also a leading cause of helicopter accidents. **How do we prepare pilots for this vital maneuver without causing so many accidents?**

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As long as there are helicopters, there will always remain the necessity for the pilot to be proficient in autorotations. Helicopters have a distinct advantage over any airplane in that when the engine stops providing enough power to keep the craft airborne, it can descend and settle safely at a place selected by the pilot in almost any condition.

However, the workload of an autorotation is formidable and unrecoverable consequences can quickly occur if the pilot's inputs are incorrect, insufficient, excessive or poorly timed. The number and nature of the skills the helicopter pilot must master to properly perform an autorotation are intimidating and pilots must receive extensive initial and then frequent recurrent training in this critical maneuver to maintain proficiency.

Unfortunately, the practice of autorotations has been and continues to be a leading cause of rotary-wing accidents. The U.S. Joint Helicopter Safety Analysis Team (JHSAT) *Compendium Report* (2000, 2001 and 2006) shows that failures in autorotation training were noted in 68 of the 523 accidents, or 13% of all helicopter mishaps.

The fatal accident of an emergency medical service (EMS) helicopter near Mosby, Missouri, on Aug. 26, 2011, revealed considerable gaps in autorotation training. On that day at about 6:41 pm CDT, a Eurocopter AS350 B2 helicopter operated by Air Methods crashed following a loss of engine power as a result of fuel exhaustion a mile from an airport. The pilot, flight nurse, flight paramedic and patient were all killed, and the helicopter was substantially damaged.

Even though the helicopter had only about 30 min. of fuel remaining and the closest fueling station along the route of flight was at an airport about 30 min. away, the pilot elected to depart the hospital and fly to that facility with the two crewmembers and the patient. The helicopter ran out of fuel within sight of the airport and then crashed after the pilot failed to make a successful autorotation.

Pictures of the accident site revealed a wide-open field that should have been an ideal emergency landing site. The aircraft's rotor blades exhibited minimal rotational energy at impact, which occurred within 10 sec. of the engine flame-out. Pictures from the NTSB hearing showed that the helicopter struck the ground approximately at 40 deg. nose low.

How could a highly trained former U.S. Army AH-64 Apache pilot have failed to make the necessary control inputs for a safe autorotation?

During simulator re-creations of the accident sequence, the pilots involved reacted to the flameout with simultaneous aft cyclic, down collective and left pedal input (the main rotor rotates clockwise in the European-built AS350, just the opposite of most American-built helicopters.) The actual flame-out in the accident flight occurred at approximately 300 ft. AGL and at a cruise airspeed of 115 kt. By using the described control inputs, the simulator pilots successfully transitioned the helicopter into autorotation, bleeding off the kinetic energy during the cyclic flare, and setting down without mishap in 27 sec.

In contrast, when the simulator scenario attempted an initial pilot reaction with just the collective and no cyclic under the same entry conditions, the machine crashed in less than 5 sec.!

The simulator flight tests conducted after this accident showed that when a loss of engine power occurs in the Eurocopter AS350 B2 at cruise airspeeds, the pilot must simultaneously apply aft cyclic and down collective in order to maintain rotor rpm and execute a safe autorotation. And these reactions must occur within about 2 sec. to maintain rotor rpm. The NTSB investigation determined that the autorotation training the pilot received was not representative of an actual engine failure at cruise speed, which likely contributed to his failure to successfully execute the maneuver.

The investigation also found that without specific guidance regarding the appropriate control inputs for entering an autorotation at cruise airspeeds, pilots of helicopters with low-inertia rotor systems may be unaware that aft cyclic must be applied when collective is lowered within seconds of losing engine power. Failing that, they may be unable to maintain control and perform a successful autorotation. The FAA and industry partners have since revised training materials to convey this information.

There is no debate within the industry on the importance of autorotation training. However, according to the FAA's Planning Autorotations, "The autorotation maneuver continues to cause problems for helicopter training providers throughout the country. The problem stems from the high number of accidents associated with the practice autorotation with a power recovery."

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Despite a well-intentioned initiative within the helicopter industry to drive accidents to record low levels, a 2011 analysis of three years of helicopter accident data by the FAA and the International Helicopter Safety Team (IHST) recognized an unacceptable increase in the helicopter accident rate. Autorotations — both actual emergencies and during training — were involved in a third of all rotary-wing accidents for that period.

There are many recommendations from industry sources on planning for autorotation training. The IHST's *How to Train to Survive a Real Autorotation* stresses the importance for autorotation training flights to be properly briefed on the ground before takeoff. This is to include a discussion of what is going to take place during the training session and what the instructor's expectations will be for the student. Instructor experience, proficiency, currency, instructor and student recency in conducting autorotations, rotorcraft characteristics and environmental conditions must be assessed and then adjustments made as necessary for each training flight.

Given the risk of a helicopter entering into an unrecoverable condition if the student makes incorrect and/or untimely inputs, it is vital during inflight training that the maneuver not be induced without warning. The U.S. Helicopter Safety Team's (USHST) *Airmanship Bulletin: Full Touchdown Autorotation Training* cautions, "A hurried, improper entry can create a very high pilot workload during the remainder of the autorotation. The CFI-H should clearly indicate how the practice autorotation will be initiated." Additionally, the IHST recommends using a verbal warning of "Practice Engine Failure Go." And if the instructor also wishes to reduce the throttle to simulate the engine loss, the student should be reminded that it does not move when the engine fails for real to avoid primacy misconception.

Rotor rpm is the most critical element in an autorotation. It provides the lift required to stabilize an acceptable rate of descent and the energy necessary to cushion the landing. The briefing should include the autorotation techniques to be used.

▶ FAA Advisory Circular 61-140A, *Autorotation Training* (dated Aug. 31, 2016), stipulates that the collective should be moved to the full down position to maintain rotor rpm immediately following a loss of power. It also reminds pilots that rapid or abrupt lowering of the collective could lead to inadvertent unusual attitudes, which, depending on altitude, may not be recoverable. The IHST recommends the lowering of the collective to decrease the angle of attack (AOA) to a tolerable level to preserve rotor rpm. The subtle difference between the wording of the FAA's AC and the IHST is likely negligible when performing practice autorotations at low density altitudes. However, at high density altitudes the rotor rpm with a fully lowered collective may be high enough to exceed the power-off limitations. (See "High Density Altitude Autorotations" sidebar.)

In the aftermath of the Eurocopter accident in Mosby, many industry publications have been revised to include the importance of the synchronous application of pedal to maintain a trim condition and of aft cyclic to set a proper attitude of the rotor tip path plane for the autorotative descent. When the collective is lowered during the entry, the rotorcraft's nose will pitch down due to dissymmetry of lift. This will increase the rotor rpm decay rate, and if not corrected soon enough, the nose-low attitude will also increase the descent rate.

During autorotation entry, a large pedal input is required (right pedal in a rotor system that spins counterclockwise) and is perhaps the largest pedal input of any maneuver. Thus, it is not uncommon for the student to apply too light or too much pedal. Failure to do so results in additional parasitic drag on the rotorcraft, causing a higher descent rate, and can result in erroneous airspeed readings.

A full discussion about autorotations with inexperienced pilots would emphasize that altitudes, positioning and pre-maneuver parameters are all essential

High Density Altitude Autorotations Are Different

As part of the preparation for this article, *BCA* visited nine flight schools in Florida (1), California (1), Hawaii (2), Montana (1) and Utah (4) to sample autorotation training in helicopters. This author flew with 13 different CFI-Hs in the Robinson R22 and R44, Schweizer 300 and Enstrom 280FX. The goal of these visits was to sample autorotation training at civilian flight schools utilizing a range of training rotorcraft. (Note to readers: These visits were "self-funded" to avoid any conflict of interest or favoritism.)

The industry's recommendations regarding instructional preflight briefings were well followed by the 13 instructors. All conducted a full discussion of what would take place during the training session and what the instructor's expectations would be for me. Each confirmed my currency and previous autorotation training, and, prior to conducting training in the Robinson models, it was necessary to assure compliance with SFAR 73, which consists of ground awareness training in energy management, mast bumping, low rotor rpm, low G hazards and rotor rpm decay. Depending on a pilot's helicopter experience, it can also require an endorsement and flight training in enhanced autorotations, rpm control without the governor, low rpm and recovery, and effects of low G and recovery.

Each of the six flight schools visited using R22s or R44s for autorotation training were "less than enthusiastic" about accepting the SFAR 73 endorsement from other flight schools and insisted on completion of their own training. That was accomplished without protest. The material covered by those six flight schools followed the standard industry recommendations. (Sidenote: Each of the CFIs who gave the ground training for the SFAR 73 endorsement provided unsolicited positive impressions about their training on Robinson-specific issues by attending the safety course conducted at the Robinson Helicopter Co. factory in Torrance, California.)

Prior to beginning autorotation practice it was necessary to get acquainted with the handling characteristics of each make and model. Since my initial helicopter training had been on a "conventional" cyclic and collective design, it took me a while to adjust to the teeter bar in the Robinsons as well as the handling characteristics of low-inertia rotor systems. There were times when the negative habit transfer from past experience made me question if indeed this "old dog" could learn "new tricks."

Some of the autorotation training sessions were done on warm summer days at density altitudes (DA) nearing the performance margin limit to safely conduct a power recovery in ground effect. Preflight preparation necessitated using a sharp pencil to closely look at the performance charts on those days.

One of the notable differences in rotorcraft handling and performance during autorotation practice was caused by DA. The rotor rpm in autorotation changes depending on a great number of variables. At higher DAs, with less dense air, there is less drag on the rotor blades. With the collective

The CFI-H at this Montana flight school (wisely) chose smooth grass and taxiways as the practice site for our power-recovery autorotation practice. Minimal traffic and proximity of suitable terrain allowed for the practice of multiple autorotations per lesson.

fully lowered, the rotor rpm will be faster at high DAs than at low ones. The rotor rpm with a fully lowered collective may be high enough to exceed the power-off limitations. A slight amount of collective pitch may be needed to maintain the rotor rpm within limits.

According to Shawn Coyle, a helicopter flight test expert, this adjustment is especially true on rotor systems with more than two rotor blades. "It may not ever be possible to fully lower the collective," he said.

Other effects on an autorotation performed at high DA include a higher rate of descent, reduced rotor rpm build in autorotation, low initial rotor rpm response, the requirement for a higher flare height and reduced engine performance for the go-around. The difference in the characteristics of the autorotation were significant compared to sea level, leaving me to ponder how many pilots get exposed to autorotation training under this challenging environmental condition.

Another interesting difference between autorotation practice in a mountainous location versus the flat terrain was the ability to accurately perceive the rotorcraft's pitch and rotor-tip path plane with respect to the horizon. For instance, when getting reacquainted with the autorotation characteristics of the Schweizer 300 at a flight school in Florida, the instructor demonstrated the relationship of the rotor-tip path plane with respect to the horizon. Maintaining this sight picture resulted in a stable (and lower workload) autorotation descent. It was nearly a textbook demonstration straight out of the FAA's *Helicopter Flying Handbook*.

In contrast, performing autorotations in mountainous terrain prevented the ability to see a flat discernible horizon. "False horizon" is a common visual illusion when operating in mountainous terrain, and this heightened the workload when trying to scan outside for the rotorcraft's and rotor-tip path plane's relationship with respect to the horizon. Without an accurate horizon it required more frequent scans of the cockpit instruments.

All but one of the flight schools was located at a busy airport, which required flying to another location to practice autorotations. Given the time spent en route to a practice area, the number of autorotations per lesson was typically limited to five or six for 1.4 hr. of block time. At an average cost of $350/hr. for the helicopter and instructor, this equates to roughly $80 per autorotation.

As discussed in the "Simulators" sidebar (page 48), there needs to be a more effective option to afford students a large number of practice autorotations to master this important maneuver. **BCA**

Information Sources

Collaborative working groups within the helicopter industry have published a wealth of informative recommendations to help flight schools and instructors. These include:

- European Helicopter Safety Team: *Risk Management in Training.*
- FAA Advisory Circular 61-140A, *Autorotation Training* (dated Aug. 31, 2016).
- FAA: *Helicopter Flying Handbook,* FAA-H-8083-21A (2012).
- FAA: *Planning Autorotations,* FAA-P-8740-71.
- FAA Special Airworthiness Bulletin SW-12-12, *Conducting Engine-Failure Simulation in Helicopters With Reciprocating Engines.*
- International Helicopter Safety Team: *How to Train to Survive a Real Autorotation.*
- International Helicopter Safety Team: *Training Fact Sheet — Energy in Autorotation.*
- NTSB Safety Alert: *Safety Through Helicopter Simulators.*
- Robinson Helicopter Co. Safety Notice SN-38 (dated July 2003 and revised in October 2004), *Practice Autorotations Cause Many Training Accidents.*
- U.S. Joint Helicopter Safety Analysis Team (JHSAT) *Compendium Report* (2000, 2001 and 2006).

components to learning this maneuver correctly and safely. Factors affecting the choice of practice area include wind velocity, wind direction and altitude.

The preflight briefing needs to evaluate the expected performance of the rotorcraft for the existing weather conditions. Critical factors will include density altitude and rotorcraft gross weight. Additionally, wind direction and velocity should be re-checked several times a day, especially during hot summer afternoons. Evaluate whether the rotorcraft has sufficient performance margin to safely conduct a power recovery in the event that a full-touchdown autorotation is inadvisable.

The FAA's Planning Autorotations urges instructors to avoid an out-of-the-way place to practice autorotations since airports have more available resources and people to come to your aid in the event the planned autorotation does not go well. It advises that when training at an airport, use a runway or smooth surface next to a runway when conducting practice autorotations in case the intended recovery results in a full touchdown. The Advisory Circular also suggests using designated hard-surface off-airport helicopter landing areas, large hard-surface parking lots, large grass fields and grass runways in good condition. If any doubt exists as to the condition of the surface, a ground or low reconnaissance should be conducted prior to conducting training.

Some flight instructors have introduced simulated engine failures by "throttle chops," *i.e.,* cutting the engine to idle. This has caused the practice autorotations to become actual autorotations. On Sept. 22, 2001, near Ramona, California, the flight instructor in a Hughes 269C initiated the autorotation demonstration maneuver between 600 and 700 ft. AGL by rolling off the throttle and splitting the needles. About 300 ft., he initiated the recovery; however, he then noticed that the engine rpm was near zero and that the engine would not respond to throttle input. At about 100 ft., the airspeed was about 40 kt., and the rotor rpm was on the low side of the green arc. The helicopter subsequently landed hard, slid forward, rolled over, and came to rest on its right side.

The company chief pilot stated that, shortly after the instructor was hired, he showed the instructor the proper technique for teaching autorotations, which did not include rolling the throttle off in flight, a procedure that could result in engine stoppage. The NTSB determined the probable cause of the accident to be the flight instructor's failure to follow the proper procedures while demonstrating a practice autorotation, resulting in a total loss of engine power and subsequent hard landing.

About four months after the accident, the FAA issued Special Airworthiness Bulletin SW-12-12, Conducting Engine-Failure Simulation in Helicopters With Reciprocating Engines. The bulletin cautions owners and operators of Schweizer 269C and 269C-1 helicopters to avoid throttle chops to full idle in order to minimize the possibility of engine stoppage.

The Robinson Helicopter Co. Safety Notice SN-38 (dated July 2003 and revised in October 2004), Practice Autorotations Cause Many Training Accidents, provides similar recommendations. It states, "do not roll throttle to full idle. Reduce throttle smoothly for a small visible needle split, then hold throttle firmly to override governor. Recover immediately if engine is rough or engine rpm continues to drop."

The FAA Advisory Circular recommends that initial training for a 180-deg. autorotation be introduced over a number of flight lessons and should start with a much higher altitude as the entry point and as training progresses, reduce the altitude and thereby gradually increase the level of difficulty. The

Simulators

Managers whose fleets include helicopters are faced with multiple choices in keeping their pilots proficient in autorotations. Should a company helicopter be used for this training? Insurance companies have clauses in contracts nullifying coverage if damage occurs during autorotation training. Then there are the practical considerations should something go wrong during practice. Any damage could put your rotorcraft in the repair shop for a long and expensive time.

The author settling into the seat of an EC-135 sim to experience first-hand the fidelity of the Level D full-motion simulator in a variety of emergency maneuvers.

Another training option is to use flight simulators, which afford the ultimate benefit of damaging only one's ego without bending metal or breaking bones when mistakes occur. Moreover, advances in simulation technology have produced remarkably accurate handling and performance characteristics mimicking the actual make/model of helicopter. Simulator training offers learning opportunities from student and instructor errors that could not be safely attempted in the actual rotorcraft.

The NTSB's *Safety Alert Safety Through Helicopter Simulators* points out that improper performance of emergency procedures has led to numerous helicopter accidents. Moreover, deteriorating weather, helicopter limitations and autorotation performance characteristics restrict what scenarios can be performed in an actual helicopter. During flight training, it is difficult to re-create the element of surprise and the realistic, complex scenarios that pilots may experience during an emergency.

"Consistent, standardized simulator training will help prepare pilots for the unexpected and will decrease the risk of an accident," it states. "Simulators can be a helpful tool for operators to provide pilot training on autorotations during any phase of flight, which reinforces the immediate responses required during actual emergencies."

At Heli-Expo 2015, industry-government workshop attendees discussed autorotation training options. Those at the invitation-only meeting included NTSB members, investigators and staff; FAA investigators and simulator inspectors; insurance industry representatives; training vendors; members of the U.S. Helicopter Safety Team and the National EMS Pilots Association; and this author.

One of the questions fielded in the meeting was whether the fidelity of simulators is sufficient to create a positive transfer of skill. FAA simulator inspectors assured the audience that as long as the maneuver stays within the sim's certification limits it would accurately replicate an autorotating helicopter's behavior.

In May 2015, we were invited to Metro Aviation's Training Center in Shreveport, Louisiana, and given the opportunity to experience first-hand the capabilities of the EC-135 Level D full-motion simulator as well as observe its usage by pilots attending recurrent training.

One of the maneuvers that ably demonstrated a simulator's capabilities was a fixed-pitch tail rotor control failure in forward flight. After reducing the collective to obtain a minimum sideslip angle and maintaining 70 KIAS or higher, the sim instructor gave the trainee an advantageous crosswind from the left. The pilot initiated a shallow approach with the nose pointing left. As the airspeed lowered below 40 kt., the procedure called for further reducing the airspeed close to the ground until the nose was aligned with the flight direction. At this point the instructor tugged on his seat belt, braced himself with a firm hold, looked over with a grin and said, "What's going to happen next is impressive. Hold on!" The trainee's initial attempts at touchdown with this simulated malfunction resulted in a wild series of gyrations.

The advantages of a simulator were clearly evident during the practice of numerous abnormal procedures. The simulators allowed a demonstration of an ideal maneuver as well as how not to do the maneuver, presenting common errors and ways to avoid them. Demonstrations were offered for variations in rotorcraft weight, density altitude, wind speed and direction, showing how each factor will individually or in combination affect performance of an autorotation.

Several dozen abnormal procedures were performed during the 2-hr. session, which was many more than could have been done in an actual rotorcraft in the same time frame. In a simulator, any part of the maneuver can be practiced in isolation. For example, the complex and synchronous movement of the collective, cyclic and pedal at the initiation of the autorotation can be practiced over and over again with the instructor critiquing each attempt until the student shows adequate performance.

And unlike a real helicopter, a simulator can be "frozen" so the instructor can show the student the nature of the situation. Time manipulation can allow error recovery, stepping back to a previous system state. Oftentimes — especially in the high workload of an autorotation — some of the control inputs made by the student do not result in an easily observed change. In the simulator, supplementary cues may be added to aid the student's perception of subtle changes in the visual field.

As one trainee I observed became more proficient, the simulator instructor programmed a variety of more challenging problems. Simulators provide the ability for "surprise" engine failures and allow students to make mistakes without jeopardizing safety. Timely use of the "freeze" button allowed the instructor to show the student the nature of the situation that had developed without any further change.

During autorotation practice in an actual helicopter, a great deal of time is spent climbing back into the traffic pattern to a position to repeat the maneuver. This limits the number of autorotations that can be practiced in a session. In a simulator, with the press of a button the helicopter is right back at the spot to start another autorotation.

The value of a simulator for training of critical procedures is unquestioned. The downside is that sending an organization's pilots to simulator training requires significant financial commitment and removes them from the work schedule.

An autorotation is a complex "perceptual motor skill," meaning that muscular movement is required as well as sensory control. An autorotation is more difficult to learn than simple motor skills and would potentially benefit from hundreds (or even thousands) of repetitions. Inexperienced pilots who are most in need of a safe training environment in which to make the many repetitions necessary could especially benefit from access to flight training devices.

Several companies have developed low-cost helicopter simulation platforms that allow trainees to practice difficult maneuvers to include autorotations, hovering, vertical reference and slung loads. These platforms are reconfigurable, allowing the device to add a variety of instrument panels, modules and rotorcraft-specific flight controls.

The industry could benefit from the utilization of flight training devices that effectively provide extensive practice of perceptual-motor skills, part-task training and augmented cueing in a realistic cockpit environment. Unfortunately, none of the flight schools we visited had these training platforms at the time. This *BCA* author intends to follow up on this promising technology. **BCA**

instructor should first demonstrate a 180-deg. autorotation with an entry from above 1,500 ft. AGL and conclude by performing a power recovery and go-around no lower than 500 ft. AGL. Once the student is proficient in performing this maneuver to the go-around point at 500 ft., the instructor should then demonstrate the 180-deg. autorotation from a lower entry point, such as at 1,000 ft. The student should then be given the opportunity to practice this maneuver with an entry at that altitude, terminating in a flare and power recovery at a safe hover altitude above the ground, until proficient from the lower altitude.

The FAA Advisory Circular also recommends the adoption of a decision check at 300 ft. AGL at which point the pilot, instructor, examiner or inspector chooses to either continue the autorotation or abort the maneuver and return to powered flight. It is important to impress upon the pilot the need to have the helicopter in a steady state at approximately 300 ft. in order to help ensure that a safe landing or power recovery can be accomplished.

The 300-ft. decision check requires the rotorcraft's airspeed to be within +/-5 kt., rotor rpm in the green, a normal rate of descent, all turns completed and the rotorcraft in proper alignment. If any of these parameters are not met, the USHST's *Touchdown Autorotations* specifies the instructor must announce "my flight controls" and take the controls, reintroduce power and commence recovery. A go-around at this stage takes advantage of the translational lift and is far preferable to the potential consequences of trying to salvage an autorotation close to the ground. Higher density altitudes would necessitate moving this decision point to a higher altitude.

Robinson Helicopter's Safety Notice SN-38 states:

Many practice autorotation accidents occur when the helicopter descends below 100 ft. AGL without all the proper conditions having been met. As the aircraft descends through 100 ft. AGL, make an immediate power recovery unless all of the following conditions exist:

(1) *Rotor rpm in the middle of the green arc.*

(2) *Airspeed stabilized between 60 and 70 KIAS.*

(3) *A normal rate of descent, usually less than 1,500 ft./min.*

(4) *Turns (if any) completed.*

The Robinson notice also states that a high percentage of training accidents occur after many consecutive autorotations. To maintain instructor focus and minimize student fatigue, it recommends limiting practice to no more than three or four consecutive autorotations.

Meanwhile, the FAA AC indicates that the predominant probable cause of autorotation training accidents is failure to maintain main-rotor rpm and airspeed within the rotorcraft flight manual's (RFM) specified range, resulting in an excessive and unrecoverable rate of descent. Each helicopter has a recommended airspeed and rotor rpm for autorotations, specified in the RFM. Throughout the autorotation, pilots should continually cross-check rotorcraft attitude, rotor rpm and airspeed and that the helicopter is in trim (centered trim ball.)

CFI-Hs must rapidly recognize and intervene if the safety of the crew and rotorcraft is jeopardized during a practice autorotation. The FAA's Planning Autorotations preflight briefing includes at what point the instructor will take control of the rotorcraft if the previously determined conditions are not met. The Advisory Circular recommends that instructors should not talk the student through corrective action or try to manipulate the controls and attempt to correct the autorotation. If proper conditions are not met at the 300-ft. decision point, then power should be immediately restored and a go-around performed.

The Mosby crash brings forth other questions regarding autorotation training. Plenty of civilian helicopter pilots have previous military rotary-wing training. The intense training to become mission-qualified in the military would thoroughly ingrain the reactions for helicopters with high-inertia rotor systems. But as the Mosby investigation revealed, the former military aviator involved had not received adequate training to re-program his reactions to a low-inertia rotor system. Logic would also extend that concern for a pilot who transitions to a rotor system that rotates opposite from one's previous experience.

How much practice is necessary to re-program a pilot's deeply trained reflexes, especially for a rotorcraft emergency in which correct control inputs must occur within seconds of sudden engine failure? To answer this question I sought out the resources from national organizations that train Olympic athletes in skiing and hockey, sports that require lightning-fast reactions to rapidly changing conditions. These organizations include physiologists, biophysicists, psychologists and neuroscientists who focus on changing seemingly small reflexes to create a competitive edge. I had the assistance of an Olympic-medalist skier and Olympic team hockey coach who put into practical terms this in-depth science. The bottom-line answer is that making fine adjustments to reflexes of highly trained athletes can take thousands of repetitions. After walking out of the U.S. Ski & Snowboard Center of Excellence training academy, I couldn't help but wonder if we in aviation are fooling ourselves by thinking a modest number of repetitions is sufficient to deeply ingrain the complex and rapid reflexes needed to respond to a sudden autorotation. Not only does that concern extend to autorotation training but also to upset recovery training in fixed-wing aircraft.

The NTSB's Mosby investigation emphasizes the importance of realistic autorotation training in all environmental conditions. However, inflight training of autorotations requires tightly controlling as much risk as possible. This includes no "surprise" simulated engine failures or practicing the maneuver in less-than-good conditions. The problem is that in the real world, an autorotation can occur at any moment without warning and in adverse environmental conditions.

Autorotation training is risky, time-consuming and expensive — and yet absolutely necessary. How best to conduct that training is a critical matter likely to reviewed and refined well into the future. **BCA**

Common Autorotation Training Errors

The FAA and numerous industry documents have compiled lists of typical student errors during autorotation training. Correct control application immediately after engine failure is necessary to establish the rotorcraft in a proper autorotative descent and to preserve the all-important rotor rpm.

If the nose is permitted to lower during the initial moments in the autorotation, it delays the recovery of rotor rpm and allows the airspeed to build rapidly beyond the optimal glide speed. A rapid correction of the cyclic aft can result in a rotor overspeed.

A student needs to learn the proper balance between having the eye scan outside of the rotorcraft versus checking the instruments without affecting the all-important task of flying the rotorcraft. There is the temptation for students to focus too much on the airspeed rather than focusing on the attitude of the rotorcraft. FAA Advisory Circular 61-140A, Autorotation Training, advises, "Do not allow the nose to pitch up or down excessively during the maneuver, as it may cause undesirable rotor rpm excursions. Pitot-static airspeed indications may be unreliable or lag during an autorotative turn. Pilots should also exercise caution to avoid using excessive rotorcraft pitch attitudes to chase airspeed indications in an autorotative turn."

While it is advantageous to land into the wind during an autorotation, continuing to turn into wind regardless of height can place the rotorcraft perilously close to the ground during the critical maneuvering portions.

Since the kinetic energy (airspeed) will be converted into rotor rpm during the flare, it is vital for students to learn the importance of maintaining a sufficient airspeed for an effective flare and power recovery.

Every autorotational flare will differ, depending on wind conditions, airspeed, density altitude, the specific make and model of helicopter, and its gross weight. The FAA Helicopter Flying Handbook FAA-H-8083-21A (2012) states in part, "Care must be taken in the execution of the flare so that the cyclic control is neither moved rearward so abruptly that it causes the helicopter to climb nor moved so slowly that it does not arrest the descent, which may allow the helicopter to settle so rapidly that the tail rotor strikes the ground . . . extreme caution should be used to avoid an excessive nose-high and tail-low attitude below 10 ft. The helicopter must be close to the landing attitude to keep the tail rotor from contacting the surface."

Other errors during the flare include flaring too little or too much as well as misjudging a proper height above the surface to begin the flare.

Failure to adjust flight path when clearly overshooting or undershooting and failure to use differing attitudes/airspeeds to adjust autorotative glide to make the landing spot are also cited as common student errors. It was interesting to bring up this question during preflight briefings.

Flight instructors who want to expand their knowledge of autorotation also have a wide selection of books from which to choose. Shawn Coyle, a helicopter test pilot instructor with more than 6,000 hr. of experience in 40+ rotorcraft, published Little *Book of Autorotations*, which is dedicated solely to the topic of landing a helicopter without engine power. This author referred to that book often after the flight lessons with the young CFIs, contemplating how they could more effectively explain and teach autorotations. **BCA**

Trends From 2016-2017 Autorotation Training Accidents

A total of 61 helicopter accident investigation reports involving an autorotation are contained in the NTSB's accident database during 2016 and 2017. Thirteen of the 61 accidents occurred during autorotation training in this two-year period. One accident resulted in a fatality. All of the other accidents involved non-fatal injuries. Two of the 13 involved turbine-powered helicopters. The rest occurred in recip-powered helicopters. Improper flare occurred in six of the 13. Lack of timely intervention by the CFI was cited in five. A loss of power during autorotation training occurred in three. Improper throttle usage, adverse winds and loss of rotor rpm were factors in one accident each.

That's the raw data. It is worth noting that the number of autorotation accidents in this two-year period was "only" 13. This is worth contemplation especially if one considers the amount of helicopter flight training that occurred during the time frame. Making sweeping pronouncements from a small number of data points is not good science. With that said, is this lower number of autorotation accidents in the period indicative of a positive reaction to the government-industry initiatives? Perhaps. The debate on whether this is a direct cause-and-effect or mere happenstance would carry good arguments on both sides.

Second, notice many important topics that are absent in these accidents. For instance, the one accident with loss of rotor rpm occurred in the final moments of a landing flare, resulting in airframe damage but no major injuries. Given the (essentially) unrecoverable condition if the rotor rpm falls below critical values, it seems apparent that flight instructors are appropriately monitoring rotor rpm during a student's practice.

Third, it is worth mentioning that none of the accidents involved flagrant deviations from the industry's recommendations. Instructors weren't practicing autorotations over a poor choice of terrain, and in all but one accident they were adhering to the recommendations for "no throttle chops." Of course, the argument can be made that these don't represent other events in the real world in which instructors were not abiding by the industry's recommendations but avoided mishaps anyway. Without FOQA data we can't definitively determine the margins of safety of a helicopter's flight condition during autorotation practice. **BCA**

Touchdown Autorotation Pros and Cons

The majority of inflight training autorotations end with a power recovery to a hover. However, there are vocal advocates who believe that learning an autorotation procedure all the way to the ground — "a touchdown autorotation" — is better since it provides the student pilot the maneuver's actual look and feel and thus heightened preparation should it happen for real. Touchdown autorotations have been a point of lively debate within the helicopter industry for quite some time and will likely continue, as it should.

The FAA Practical Test Standards do not require applicants for the private, commercial or ATP certificate to demonstrate proficiency in full touchdown autorotations. Neither does 14 CFR 135 during initial and recurrent training. However, the Flight Instructor Practical Test Standards do require a CFI applicant to demonstrate proficiency in full touchdown autorotations.

The U.S. Helicopter Safety Team's (USHST) *Airmanship Bulletin: Full Touchdown Autorotation Training* highlights the pros and cons of full touchdown training. Advocates believe it increases pilot confidence and thus reduces the chance of a catastrophic outcome to a real engine failure. They also believe that the power recovery aspect of the autorotation training does not resemble the real situation and may even build a false sense of security on the part of the pilot.

In comparison, advocates for power-recovery claim that the increased risk of damaging the rotorcraft in a full touchdown maneuver is not worth the benefit gained over a power recovery to the hover. They also believe that with the increased reliability of today's modern engines, the industry would damage more rotorcraft practicing for an event that rarely occurs. The USHST's Airmanship Bulletin does not take either side in this debate.

The U.S. Joint Helicopter Safety Analysis Team (JHSAT) identified intervention recommendations associated with full touchdown autorotations for training. These include a quality training program and a CFI with judgment and decision making focused on following the student more closely during the maneuver and an emphasis on training for maintaining awareness of cues critical to safe flight. Also, it maintains that exceptional risk management and adherence procedures are highly important.

Helicopter organizations must assess the risk of performing their training autorotations to the ground. There are associated costs involved in doing this including cumulative wear and tear on the rotorcraft.

Organizations whose insurance won't permit full touchdown autorotation training in their helicopters but who still want their pilots to experience it can attend training at well-known vendors that provide expert instructors who teach full touchdown autorotations for a living and have a rather respectable safety record teaching this potentially high-risk maneuver **BCA**