ACT ARC Recommendation 23-2
Part 135 Helicopter Operations Spatial Disorientation Training

I. Submission

The recommendation(s) below were submitted by the Spatial Disorientation Training Workgroup (SDT WG) for consideration by the Air Carrier Training Aviation Rulemaking Committee (ACT ARC) Steering Committee at F2F-27, January 25-26, 2023. The ACT ARC Steering Committee adopted the recommendations, and they are submitted to the Federal Aviation Administration (FAA) as ACT ARC 23-2.

II. Definitions

Distraction means the diversion of attention away from the primary task of flying.

Flight Simulation Training Device (FSTD) means a full flight simulator (FFS) or a flight training device (FTD).

Loss of Control in Flight (LOC-I) is a categorization of an accident or incident resulting from a deviation from the intended flightpath.

Maneuver-Based Training (MBT) means training that focuses on a single event or maneuver in isolation.

Prevention means actions to avoid any divergence from a desired aircraft state.

Scenario-Based Training (SBT) means training that incorporates maneuvers into real-world experiences to cultivate practical flying skills in an operational environment.

Spatial Disorientation (SD) is a term used to describe a variety of incidents occurring in flight in which pilots fail to sense correctly the position, motion or attitude of the aircraft or of themselves within the fixed coordinate system provided by the surface of the Earth and the gravitational vertical.[1]

Startle means an uncontrollable, automatic muscle reflex, raised heart rate, blood pressure, etc., elicited by exposure to a sudden, intense event that violates a pilot's expectations.

Surprise means an unexpected event that violates a pilot's expectations and can affect the mental processes used to respond to the event.

Transfer of Training means the ability of a trainee to apply knowledge, skills, and behavior acquired in one learning environment (*e.g.*, a classroom, an FSTD) to another environment (*e.g.*, flight). In this context, "negative transfer of training" refers to the inappropriate generalization of knowledge or skills learned in training to line operations.

Undesired Aircraft States are characterized by divergences from parameters normally experienced during operations (*e.g.* aircraft position or speed deviations, configuration of flight controls, or incorrect systems configuration) associated with a reduction in margins

[1] Benson, A., "Spatial Disorientation – General Aspects". In J. Ernsting & P. King (Eds.), *Aviation Medicine* (1988) (pp.277-296).

of safety. Often considered at the cusp of becoming an incident or accident, undesired aircraft states must be managed by flight crews.

III. Statement of the Issue

In its report on a January 26, 2020, fatal accident in Calabasas, California involving a Sikorsky S–76B helicopter, the National Transportation Safety Board (NTSB) issued the following recommendation:

> **NTSB Recommendation A-21-5**
> *Require the use of appropriate simulation devices during initial and recurrent pilot training for Title 14 Code of Federal Regulations Part 135 helicopter operations to provide scenario-based training that addresses the decision-making, skills, and procedures needed to recognize and respond to changing weather conditions in flight, identify and apply mitigation strategies for avoiding adverse weather, practice the transition to the use of flight instruments to reduce the risk of spatial disorientation, and maintain awareness of a variety of influences that can adversely affect pilot decision-making.*

The ACT ARC formed the SDT WG, in part, to address Recommendation A-21-5.

Additionally, a 2017 USHST analysis of 104 US fatal helicopter accidents between 2009-2013 revealed that half of those accidents were linked to Loss of Control In Flight (LOC-I), Unintended Flight in Instrument Metrological Conditions (UIMC) or Low Altitude (LALT) operations.[2] The United States Helicopter Safety Team (USHST) set out to address these alarming results, activating over a dozen Helicopter Safety Enhancements (H–SEs) considered to be most effective in addressing these top three common occurrence categories.

In a subsequent review of the FAA's accident database, the USHST assessed SD was a likely influence in 130 fatal degraded visual environment (DVE) accidents between 2000-2019. In response, the USHST published two documents in 2020 to help educate the industry and underscore the importance of SD simulation and SBT.

- H–SE 123: Recommended Practice: Simulation Training for Aviation Decision Making, Apr 2020[3]
- H–SE 127A: Recommended Practice: Spatial Disorientation Induced by a Degraded Visual Environment: Training & Decision-Making Solutions, Dec 2020[4]

IV. ACT ARC Recommendations

a. The ACT ARC recommends the FAA issue or revise guidance to part 135 helicopter operators that will allow them to incorporate SD training into their training programs. This guidance should address theoretical and practical training, including scenario training.
b. The ACT ARC recommends that the FAA issue or revise guidance to potential users of SD training devices that will allow them to select suitable devices and incorporate them into their training program. This guidance should address considerations in the selection and use of SD training devices, including device

[2] USHST, "Helicopter Safety Enhancements, Loss of Control – Inflight, Unintended Flight in IMC, and Low-Altitude Operations." 2017
[3] USHST, "H-SE 123: Recommended Practice: Simulation Training for Aviation Decision Making," 2020
[4] USHST, "H-SE 127A: Recommended Practice: Spatial Disorientation Induced by a Degraded Visual Environment: Training & Decision-Making Solutions," 2017

capabilities, operational considerations, financial considerations, and training objectives.

c. The ACT ARC recommends the FAA encourage the United States Helicopter Safety Team (USHST) to develop Helicopter Safety Enhancements (H–SE) that incorporate the curriculum and training methods described in this document.
d. The ACT ARC recommends the FAA consider revising part 135 helicopter training requirements to include the curriculum and training methods described in this document.

V. Rationale and Discussion

In approaching its tasking, the SDT WG looked to existing guidance with respect to upset prevention and recovery training (UPRT), as SD is a factor in events leading to loss of control in flight (LOC–I) and SD training bears numerous parallels to UPRT.[5] ICAO Doc 10011, Manual on Aeroplane Upset and Recovery Training, notes that LOC-I accident data lists “one or more flight crew members becoming spatially disoriented” as one of the pilot/human-induced contributory factors to LOC-I. Additionally, there are several important concepts found in Advisory Circular (AC) 120-111, UPRT, that the SDT WG evaluated as critical to properly delivering SD training. The emphasis on enhanced instructor training and understanding the limitations of the devices are at the top of the list. The AC also describes SD as one of the casual factors that could contribute to an upset, and also provides common illusions associated with loss of control in flight (LOC-I) events.

The SDT WG members discussed and reached concurrence on a general philosophy for comprehensive spatial disorientation training, to include incorporation of training devices. Given that approximately 80 percent of all aviation accidents involve human factors,[6] the SDT WG firmly believes that increased emphasis on SD training beyond what is contained in current guidelines is needed. Although training related to human factors is difficult to design and administer—especially for SD training—the ACT ARC supports a comprehensive approach for SD training programs through incorporation of theoretical, ground-based, and in-flight elements to the maximum extent possible.

In arriving at this philosophy, the SDT WG identified a number of aspects essential to effective recognition and avoidance of conditions that could lead to spatial disorientation, as well as techniques to assist in recovery from SD should a pilot experience it. First, the ACT ARC regards SD training to be foundational. That is, pilots should complete SD training at the earliest opportunity, ideally at the primary flight training level, and at every level of licensing thereafter.[7]

Second, effective SD training should include a combination of theoretical and practical training as detailed below. Similar to other areas of training where effective habit patterns should be introduced—such as instrument flight training—effective SD training should build progressively on the foundations established at the primary level.

---

[5] The objective of UPRT is to equip the pilot to prevent or correct an undesired aircraft state; the objective of spatial disorientation training is to prevent or correct an undesired human state, which is more difficult.

[6] Ch. 13, Helicopter Flying Handbook (FAA-H-8083-21B), Federal Aviation Administration, 2019.

[7] Although not within the scope of SDT WG TOR II.2, which is limited to part 135 helicopter operations, the SDT WG believes the FAA should consider revising the Instrument Flight Handbook to address spatial disorientation more comprehensively at a foundational level. The FAA could also consider additional publications, such as brochures, advisory circulars, or revised Aeronautical Information Manual content, to foster better awareness and understanding of SD risk.

Participating in a comprehensive training program that incorporates solid ground academics along with ground-based and in-flight simulation, further adds to the effectiveness of spatial disorientation training.

- Theoretical Training – Training that consists of ground school in the physiological systems and structures involved, and the mechanisms by which pilots experience spatial disorientation.[8]
- Practical Training – Training that consists of exposure, in an aircraft or suitable ground-based training device, to stimuli likely to produce spatial disorientation.[9] Such exposure allows the pilot to correlate sensations and perceptions experienced during spatial disorientation with the knowledge obtained from theoretical training.

Theoretical training establishes the foundation from which situational awareness, insight, knowledge, and skills are developed, and therefore must be accomplished prior to practical training of the associated flight events. To ensure sufficient retention, practical training should occur within a reasonable time after theoretical training.

Finally, SD training should be both frequent and operationally relevant.

- Frequent Training – Frequency of training signifies the incorporation of spatial disorientation training into each level of pilot certification and qualification, including initial and recurrent training cycles at the air carrier level.
- Operationally Relevant Training – Operationally relevant training describes the use of safety data to identify and emphasize illusions most frequently involved in accidents and incidents related to an organization's operational environment. The SDT WG expressed operationally relevant training by assigning priorities to the illusions considered when assessing devices and technologies in the column labeled "Training Priority" in Appendix A, Table A-2. The information is intended to guide operators and training providers as they consider selection of training devices and design training programs. Such data could include, for example, accident and incident reports, Safety Management System (SMS) data, and Aviation Safety Action Program (ASAP) or other safety reports.

The ACT ARC recommends FAA guidance encourage part 135 operators to adopt SD training methods that generally conform to this training philosophy, although individual training programs may vary based on needs and context.

Training Curriculum

An effective SD training curriculum provides pilots with the knowledge and skills to avoid conditions conducive to SD, recognize the onset of SD, and recover. The Appendices to this recommendation contain sample curricula including theoretical and practical spatial disorientation training elements to support development of SD training

Training should focus on avoiding an SD incident rather than waiting to recover from one. Prevention training prepares pilots to avoid incidents, while recovery training intends to avoid an accident if an SD encounter occurs. While many other important training tasks cover how a pilot must deal with aircraft or environmental problems

[8] Theoretical training is the only element of spatial disorientation training currently included in pilot certification standards and training requirements.

[9] It is noted that exposure to a given stimulus does not guarantee that the pilot exposed to it will experience the intended illusion, or any illusion at all.

(external stimuli), SD events involve problems with the pilot themselves, and therefore require a different training philosophy.

While theoretical training in human physiology and the mechanisms that cause SD are important for pilots to learn, SD theoretical training must shift to a more "pilot-centric" understanding of these topics, rather than a "medical-centric" one. This basic understanding of the manner in which a human pilot may become disoriented in flight must be revisited and reinforced throughout their career. SD Practical training must accompany theoretical training for the SD training program to be effective. A pilot who has successfully completed SD training will demonstrate knowledge of basic SD theoretical topics and skill in avoiding, recognizing, and—if necessary—recovering from an SD event.

While the devices available and means of conducting this practical training vary widely, there are basic elements that must be included. Practical training must include a demonstration of select visual and vestibular illusions in order for the trainee to experience some sort of disorientation. This experience will raise the trainee's interest in SD and determine their mindset for the rest of the training. (Note: It is not necessary to experience actual spatial disorientation for training to be successful. Different pilots may be more or less disoriented than others given the same stimuli. Additionally, a pilot may have a different experience given the same conditions on different days. This is another reason why the ACT ARC recommends SD training throughout a pilot's career.)

Prevention
Training with an emphasis on avoidance of conditions conducive to SD provides pilots with the skills to recognize conditions that increase the likelihood of SD.[10]

Awareness and prevention of SD are particularly relevant for:

- pilots who are only rated for VFR;
- pilots who are IFR-rated, whether current or not;
- pilots flying VFR rotorcraft, which are inherently unstable at low speed and frequently lack force trim and/or an automated flight control system (AFCS);
- pilots flying in single-pilot operations.

Aeromedical factors that may also increase the likelihood of SD include:

- fatigue
- medication
- smoking
- altitude (hypoxia)

Autopilot/Auto Flight Systems
Use of Autopilot in Normal Operations. Part 135 air carriers should continue to develop policies that encourage manual flight operations when appropriate. Operational policies should be reviewed to ensure there are appropriate opportunities for pilots to exercise manual flying skills, such as in low workload conditions. In addition, policies should be developed or reviewed to ensure that pilots understand when to use the automated systems—for instance, during high workload conditions or for airspace procedures that require precise operations. Operational policies should ensure that all pilots have the

[10] While this Recommendation is, as an ACT ARC product, limited in scope to training, it is worth noting that operators can take actions outside training to avoid conditions conducive to SD. General and specific operational policies, procedures, and decision making can proscribe operations in conditions likely to be conducive to SD, and can dictate an appropriate course of action (e.g., exit maneuver) if such conditions are encountered unexpectedly.

appropriate opportunities to exercise manual flight knowledge and skills in flight operations.

Use of Autopilot during SD Recovery. Autopilot systems may have limitations that prevent them from being helpful during an SD encounter. A thorough understanding of autopilot limitations and capabilities will allow the pilot to discern the best course of action regarding the use of auto flight systems during recovery.

<u>VFR Instrument Crosscheck</u>
An enhanced VFR Instrument Scan is crucial to preventing the onset of SD, particularly during decreased visibility conditions. The scan is not intended to extend or continue flight into a Degraded Visual Environment, but rather provide tools to prevent disorientation as the pilot executes the enroute decision trigger.

Once the pilot is unable to maintain aircraft attitude control by reference to the natural horizon, the operation is considered to be in Instrument Meteorological Conditions (IMC), regardless of the prevailing weather conditions. At this point, pilots should understand that the only way to control the aircraft safely is by using and trusting the flight instruments. Attempts to control the aircraft partially by reference to the flight instruments while searching outside of the aircraft for visual conformation of the information provided by those instruments results in inadequate aircraft control.

Scanning should be part of a complete training program, encouraged to be used at all times for greater situational awareness, and considered crucial anytime conditions decrease to MVFR or below.

Training Methods
The training methodology for SD training should follow the building block approach of first introducing essential concepts and academic understanding before progressing to the practical application of those skills in actual or simulated flight.

Similarly, familiarity with select illusions, aircraft characteristics (including automation), SD avoidance techniques and development of basic recovery skills through MBT should precede their application in SBT. This progressive approach will lead to a more complete appreciation of how to avoid, recognize, and recover from SD. These training curriculums should contain the elements and events described in Appendix A, Sample Spatial Disorientation Training Curriculum.

The ACT ARC envisions theoretical training made up of individual training (video, computer-based training, or self-study) and instructor delivered training. Theoretical training may also include interactive, scenario-based discussions or exercises, in which the objective will be for students to demonstrate proper aeronautical decision making.

The ACT ARC envisions two types of practical training, MBT and SBT, to both train the building blocks as well as put them into practice in a SBT event.

MBT would consist of execution of multiple SD-training tasks, each of which is intended to expose the pilot undergoing training to conditions conducive to experiencing one or more illusions associated with SD. This training could be accomplished in an aircraft, with aid of an in-aircraft training device, or in a ground-based trainer or other device capable of producing the necessary stimuli.

MBT should include exposure to common illusions, distance estimation as it applies to flight visibility, use of automation, VFR instrument crosscheck techniques, flight by reference to instruments, enroute decision triggers, SD recovery techniques and takeoff/landing considerations such as dust/snow/black hole effect. While some decision making is naturally included in these topics, the emphasis of MBT is building the tools the pilot will use during the scenario segment of SD training.

SBT is decision-making oriented, with a greater focus on training pilots to avoid SD, rather than to recognize or recover from it. The goal of SBT is to develop perception and decision-making skills relating to SD avoidance, recognition, and recovery, while providing the pilot with an opportunity to use the skills learned in MBT in a realistic scenario. SBT would normally be used after MBT. Such training would include pre-flight discussions and decision-making exercises, as well as flight training in an aircraft or ground-based training device. SBT should be tailored to the operator's and student's training needs based on contextual factors and relevant data, including advanced qualification program or similar training and performance data.

SBT could be accomplished in an aircraft or ground based device. Successful completion would include recognition and avoidance of a SD threat in response to enroute decision triggers, or recognition of and recovery from onset of SD.

NOTE: SD avoidance, recognition, and recovery techniques are not to be evaluated in proficiency checks, line-oriented evaluation (LOE), or by other jeopardy events.

Use of Devices in Training

During development of Proposed Recommendation SDT-1, the SDT WG identified SD device selection considerations in Table A-1. While not an exhaustive list, it enables a general assessment of SD device capabilities. Primary considerations evaluated in the table include the ability of the devices to induce onset and enable recognition and recovery of various visual illusions and vestibular illusions.

SD training devices fall into two broad categories: in-aircraft devices and ground-based devices.

In-Aircraft Devices

In aircraft training provides the most realistic vestibular training by using aircraft movement to produce the movement required for vestibular illusions. As with any in aircraft training, risk is increased (compared with ground-based device training) and consideration must be given to conducting safe and effective training. The NTSB highlighted this concern in the Calabasas report with concern for the rapid development of climbs and descents as well as other inflight upsets.

A combination of visual and vestibular illusions allows the most effective training for SD. Traditional view limiting devices, such as hoods, foggles, or curtains, provide the potential to induce vestibular illusions, but are not capable of inducing visual illusions because they allow no visibility in the portion of the visual field blocked.

Visibility Simulation Systems, which use a controllable film to replicate variable visibility conditions, provide conditions conducive to visual illusions, while the natural movement of the aircraft provides the potential for vestibular conditions. The combined illusions can lead to cognitive confusion that has resulted in SD accidents. This combination of illusions creates a realistic environment to train SD.

Training with Visibility Simulation Systems has the potential for higher risk than traditional view limiting devices. Historically, view limiting devices were used for standard instrument training. This training, while extremely valuable, differs greatly from training for SD. This risk should be mitigated through safety/instructor pilot proficiency to include limiting the safety/instructor pilot interaction with the training system during the training event.

System design characteristics can also mitigate the risk of the system. Reducing distractions of safety pilot/instructor pilot will greatly enhance the safety of the training. This can be accomplished through automation of training functions. Directly addressing the NTSB concern of developing unsafe aircraft states during in-aircraft training, a training system should use exceedances in climb and descents as well as other inflight upsets (attitude or altitude) to halt the training.

By ensuring instructors are highly trained in the use of these devices, reducing safety pilot/instructor pilot distractions and designing failsafe systems that will return the pilot to visual conditions before exceeding pre-set aircraft parameters, the risk to in aircraft training can be mitigated.

Ground-Based Devices

Ground-based simulation devices used for SD training have a wide variety of capabilities, features, and limitations, and may offer a cost-effective and safe alternative to performing training in an aircraft or provide the capability to train certain tasks which cannot be easily trained in an actual aircraft.

Due to the wide variety of devices available for SD training, care must be taken to ensure the selected device effectively simulates the environment needed for the training. Level C and D FFS are extremely realistic in presentation of a representative flight deck, but are generally not capable of creating the conditions conducive to fully developed vestibular illusions due to limitations in the motion platform. Devices designed specifically for SD training may include more capable motion platforms, but present a more generic cockpit and flight model simulation. Additionally, most ground-based SD training devices are not capable of producing sustained g-loading. Aircraft maneuvering during the recovery phase will be more realistic in an actual aircraft due to the true forces felt by the pilot.

The type of motion platform employed is the largest design factor as to what SD profiles can be trained, and to what degree an SD illusion can be effectively experienced or demonstrated. For instance, an AATD or BATD can be used to train visual illusions, while those platforms that employ motion can train visual and vestibular illusions. However, it is important to understand that “not all motion is created equal.” Therefore, it cannot be emphasized enough that those incorporating SD training into their programs fully understand the details of each illusion and the conditions they intend to replicate. It is equally important to understand the capabilities and limitations of each device to avoid negative transfer of training.

Another important aspect regarding ground-based SD devices is that they are inherently low risk, with a high degree of reward, due to the controlled environment in which they operate. Ground-based simulators have long proven they are capable of multifaceted training events, not necessarily specific to SD. While not all of the illusions are capable of being replicated with traditional six degree-of-freedom (6DOF) simulators, there are a great number that can be demonstrated with a large degree of efficacy. Moreover, some events in a simulator count as a training or checking event under Title 14 Code of Federal Regulations (14 CFR) part 135 operations as previously outlined. This creates an intrinsic benefit for the pilot and company requiring the training. The high fidelity requirements of Level D simulators represent increased transfer of training opportunities when well-developed SD SBT events—as described under Training Methods—are employed in recurrent training.

Dedicated SD trainers—devices built with the primary purpose of re-creating flight environments that produce SD—are being deployed in increasing numbers, especially among military aviation operators. The current generation SD trainers are capable of pilot-flown interactive flight simulation with visual, motion and immersive fidelity focusing on the ability to produce SD events in a timely and realistic manner. The key advancements are found in the motion capabilities and the out-the-window (OTW) imagery representation. These SD trainers are capable of generating continuous yaw motion and specific motion cues that create erroneous input to the human sensory system insidiously. Furthermore, SD trainers with centrifuge motion capability can generate sustained linear acceleration and increased G forces which are inherent to maneuvering aircraft, and is a known causal factor of vestibular illusions. Delivery of complex motion sensory inputs through an automated advanced algorithm allows a seamless and realistic transition from fully oriented flight into a disorientated state. OTW imagery in these purpose built SD trainers not only produce a realistic flight visual experience, but are capable of altering the imagery to reproduce in-flight visual illusions.

As with any 6DOF system, purpose built SD trainers can incorporate differing levels of fidelity, and accurate depiction of VFR and IFR flight environments. Additionally, cloud and terrain appearances can be altered to produce the visual illusions associated with misinterpretation of horizons and terrain appearance. The flexibility and adaptability of these features allow these SD trainers to expose pilots to the most challenging SD situations in a safe and controlled environment.

Emerging Technologies

One of the salient observations from the device analysis completed by the SDT WG during SDT-1 is that—although the tables capture well the state of current capabilities—it was difficult to express the group's enthusiasm regarding future developments of these devices and the potential of emerging technologies. The rapid improvement of current in-aircraft and ground-based devices, coupled with the development of emerging technologies, presents an opportunity to incorporate effective SD training at all levels of licensing—a key recommendation of the WG. The technology of today's in-aircraft view limiting systems and ground-based simulators is impressive, and the WG believes the emerging capabilities of Virtual Reality (VR), Mixed Reality (MR), and Augmented Reality (AR)—collectively Extended Reality (XR)—must be considered and evaluated in detail. The potential of XR, through developments in goggle technology, haptic feedback, and other features—paired with advanced motion platforms to create immersive, scenario-based, high-fidelity SD training—should not be overlooked. As these new capabilities and technologies emerge, and as the development of current in-aircraft and ground-based simulators continue, the WG strongly recommends that resources be applied to assess their potential using the methodologies and recommendations proposed by the ACT ARC in this document.

Use of Devices by Certificate Holders

The SDT WG discussed whether there are any obstacles to use of ground-based devices, including emerging technologies, for training by operators such as air carriers or part 135 operators. It appears that the applicable regulations provide some latitude for the use of training devices other than FSTDs qualified under 14 CFR part 60. In particular, Sections 61.4(c), 135.323(e), 135.335(a), 121.403(b)(2), and 121.921(b) contain language that seems to contemplate use of such devices with approval. [11]

[11] 14 CFR § 61.4 allows the Administrator to approve a device other than an FSTD for specific purposes. The other identified sections of 14 CFR refer to use of "other training devices", "other training aids", or "other training equipment" in training if approved by the Administrator.

Importance of the SD Instructor
Regardless of whether practical training is administered in aircraft or a ground-based device, a trained and qualified instructor with appropriate knowledge is key to effective training. The safety implications and consequences of applying poor instructional technique or providing misleading information are more significant in SD training compared with some other areas of pilot training. Therefore, an essential component in the effective delivery of SD training is a properly trained and qualified instructor who possesses sound academic and operational knowledge.

Instructor knowledge of the subject areas below ensures accurate SD training and minimizes the risk of negative transfer of training. The focus of instructor training should be on the practical application of these principles and the evaluation of a pilot's understanding of the airplane's operating characteristics.

- *Limitations of the Training Device:* Instructors must complete training on the data and motion limitations for each specific FSTD used for SD training, with emphasis on areas that have the potential to introduce negative transfer of training. Training on the limitations of the specific FSTD will enable instructors to provide SD training consistent with the capabilities and performance of the specific aircraft type. This comprehensive instructor training will not only increase instructor standardization and the quality of SD training, but it will also reduce the risk of negative training that could easily occur with an untrained instructor.
- *Distraction:* Instructors should have an awareness of how distractions can lead to loss of situational awareness and how to effectively use distractions in training. Appropriate use of distractions can also assist the instructor in creating a situation to induce startle. Instructors should learn about different distractions that can affect a flight crew.
- *Recognition and Recovery Strategies:* Instructors should be able to convey how to recognize the onset of SD and to apply appropriate recovery strategies. Training should include specific examples, in both academic discussion and practical demonstration.
- *Recognition and Correction of Pilot Errors:* Errors may occur in flight operations if the errors are not identified and corrected during training. Instructors should be aware of the consequences of failing to recognize and correct pilot errors. Instructors should be familiar with common pilot errors, be able to identify the root cause, and provide training to avoid errors.
- *Type-Specific Characteristics:* Different aircraft have unique characteristics that may prevent successful recovery in the event the normal flight envelope has been exceeded during an SD encounter. SD instructors should know the unique characteristics regarding rotor system and g-loading limitations and how they may affect the outcome of the flight.
- *Operating Environment:* Instructors should review how certain operating environments are more prone to SD than others (*e.g.* areas prone to flat light, other low contrast areas, night operations, IMC, etc.). Emphasis should be placed on environmental characteristics common to the trainee's normal areas of operation.
- *Startle or Surprise:* Considering many instances of SD are unrecognized, pilots may be startled or surprised, adversely impacting recognition or recovery. Instructors need to plan scenarios to balance potential for startle or surprise while applying sound judgment with respect to realism and fidelity, while respecting the capabilities and limitations of the aircraft or training device being used. It is

crucial for the instructor to adopt and foster a spirit of collaborative learning when inducing startle or surprise so as not to inappropriately attempt to trap a pilot or destroy confidence in the training session.

- *Benefits of Demonstration:* Some sensory illusions may be more assessable, trainable, and effective when instructors demonstrate them from a pilot seat.
- *Assessing Pilot Performance to Completion Standards:* Instructors should be able to assess when an appropriate level of proficiency and awareness is achieved. Instructors should be trained on how to judge pilot performance on the SD events and determine whether the required learning objectives have been met. This should not be a simple pass/fail situation but rather an assessment of the pilot's overall awareness of the conditions conducive to SD, the ability to recognize the onset, and recover from an SD event if necessary.

SD training instructors must meet the following requirements:

- Be able to teach, assess, and debrief the elements included in the training programs they are conducting;
- Be trained and qualified to conduct training in the device to be used for the training;
- Understand the limitations (ability or lack thereof) of the device being used to simulate SD.

Other Considerations

In addition to device capabilities, potential users of SD training devices should consider the following:

- Operational considerations:
    - Device availability. Limitations on device availability may include, but are not limited to, geographic location, operational tempo at the training facility, maintenance downtime, number of devices available, etc.
    - Instructor availability. Even if a student and device are available, a qualified instructor is needed to conduct training.
    - Schedules of students and instructors. It is acknowledged that operators must balance the needs between operational demands and training activities, and that there is a finite amount of time to address all requirements, including SD training. Operators should take advantage of any opportunity to integrate SD training into existing training programs.
- Financial considerations – Absent a mandate, there is low incentive for operators to expend financial resources to obtain high quality, high fidelity SD training capabilities. Discussion of cost/benefit analysis – with unlimited resources and access to devices, operators could significantly reduce the rate of SD accidents. Incentives for operators and training providers could provide some relief to financial challenges.
- Training objectives – Decisions on device suitability will be driven by training objectives, which are, in turn, driven by factors such as type of operation, the environment in which operations will take place, etc.
    - Actual inducement of an illusion. For initial training, it is effective for the pilot to experience some level of actual disorientation. This raises their interest in SD training and emphasizes the need to avoid flight conditions conducive to SD.

- Risk based decision-making. At more advanced training levels, particularly in recurrent training, training should focus on recognition of SD threats and mitigating actions.

USHST HSEs/Rulemaking
The ACT ARC recommends the FAA consider actions to encourage operators and other organizations administering training to adopt the SD curriculum elements and training methods described in this document. The most direct and effective way to do this would be to revise Title 14 Code of Federal Regulations (14 CFR) part 135 to require certificate holders to include such content in their training programs. Pending regulatory action, the ACT ARC recommends the FAA work with the USHST to encourage adoption of H–SEs calling for incorporation of the recommended SD training practices and content into part 135 air carrier training.

VI. Background Information

Recommendation 23-2 addresses item 2 in the SDT WG Scope of Work and ACT ARC Initiative #47 (see below):

<u>SDT WG Scope of Work:</u>

1. * * *
2. Develop recommendations for the use of simulation training devices for spatial disorientation training for part 135 helicopter pilots. These recommendations should address—
   a. Curriculum content to be considered, to include adverse weather, use of flight instruments, and other influences that can adversely affect pilot decision-making;
   b. Training methods, to include SBT;
   c. How the training devices described in Item 1 can be incorporated into spatial disorientation recognition and mitigation training.

<u>ACT ARC Initiative:</u>

Initiative #47: Examine current training for spatial disorientation in part 135 helicopter operations. With consideration for using simulation technologies, develop scenario-based training to be used in initial and recurrent part 135 training that addresses helicopter pilot decision-making, skills, and procedures needed for recognizing and responding to the onset of spatial disorientation.

<u>Source Report</u>

National Transportation Safety Board (NTSB) Report AAR-21/01

<u>References</u>

- Proposed Recommendation SDT–1
- Helicopter Flying Handbook (FAA-H-8083-21B, as revised)
- Airplane Flying Handbook (FAA-H-8083-3C, as revised)
- Instrument Flying Handbook, Chapter 3: Human Factors (FAA-H-8083-15, as revised)
- Helicopter Instructor's Handbook (FAA-H-8083-4, as revised)

- Aviation Instructor's Handbook (FAA-H-8083-9B, as revised)
- Spatial Disorientation and Aerospace Medicine Reference Collection, Spatial Disorientation Videos
- Pilot's Handbook of Aeronautical Knowledge, Chapter 17: Aeromedical Factors (FAA-H-8083-25, as revised)
- Safety Alert for Operators (SAFO) 13002, Manual Flight Operations
- Information for Operators (InFO) 10010, Enhanced Upset Recovery Training
- Airline Transport Pilot Practical Test Standards for Helicopter (FAA-S-8081-20)
- Commercial Pilot Practical Test Standards for Rotorcraft (Helicopter and Gyroplane) (FAA-S-8081-16B)
- Private Pilot Practical Test Standards for Rotorcraft (Helicopter, Gyroplane) (FAA-S-8081-15A)
- Flight Instructor Practical Test Standards for Rotorcraft (Helicopter, Gyroplane) (FAA-S-8081-7B)
- Flight Instructor Instrument Practical Test Standards for Airplane and Helicopter (FAA-S-8081-9D)
- Instrument Rating Practical Test Standards for Airplane, Helicopter, and Powered Lift (FAA-S-8081-4E)
- Order 8900.1, Volume 3, General Technical Administration
- Order 8900.1, Volume 5, Airman Certification
- AC 120-109A, Stall Prevention and Recovery Training
- AC 120-51, Crew Resource Management Training
- AC 120-111, Upset Prevention and Recovery Training
- AC 61-136B, FAA Approval of Aviation Training Devices and Their Use for Training and Experience
- AC 120-114, Pilot Training and Checking (14 CFR Part 121 Subparts N and O, Including Appendices E and F).
- FAA Safety Brochure: Spatial Disorientation: Why You Shouldn't Fly by the Seat of Your Pants.
- FAA Safety Brochure: Spatial Disorientation: Visual Illusions
- US Helicopter Safety Team, Recommended Practice: Spatial Disorientation Induced by a Degraded Visual Environment, Training and Decision-Making Solutions, Helicopter Safety Enhancement 127A
- US Helicopter Safety Team, Recommended Practice: Simulation Training for Aviation Decision Making, Helicopter Safety Enhancement 123
- HAI Training Group, HAI Decision-Making And IIMC: A Training Reference Guide for Aircrews, https://rotor.org/resources/hai-decision-making-and-iimc/
- Spatial Disorientation Training – Demonstration and Avoidance Research and Technology (RTO) TR-HFM-118 (NATO)
- ICAO Doc 10011 Manual on UPRT (ICAO)
- IIMC-UIMC Training Methodology (Helicopter Institute)
- Defensive Flying for Pilots: An Introduction to Threat and Error Management Ashleigh Merritt, Ph.D. and James Klinect, Ph.D. (The University of Texas Human Factors Research Project – The LOSA Collaborative): http://www.skybrary.aero/bookshelf/books/1982.pdf.
- Culture, Threat, and Error: Assessing System Safety, Robert L. Helmreich, University of Texas Human Factors Research Project, The University of Texas at Austin: http://158.132.155.107/posh97/private/culture/culture-threat-error-Helmreich.pdf.

Attachments

Appendix A: Sample Spatial Disorientation Training Curriculum

Appendix A – Sample Spatial Disorientation Training Curriculum

The Spatial Disorientation Training curriculum consists of ground and flight training modules.

Ground Curriculum Segment

Below is intended to be a general overview of a training program for Spatial Disorientation (SD). These topics are what the ACT ARC determined should be covered in ground academics. Organizations should adapt the outline as necessary to address the operational aspects of their environment.

1. Introduction to Spatial Disorientation

Overview: General overview of Spatial Disorientation

- Define SD
  - Our natural inability to maintain our body orientation and/ or posture in relation to the surrounding environment at rest and during motion – *FAA Spatial Disorientation Pamphlet*
- Background of SD accidents
  - Failed/Lack of Planning
  - Bad Aeronautical Decision Making
  - Late Aeronautical Decision Making
  - Lack of Understating on Conditions Conducive to Spatial Disorientation
  - Lack of Understanding of Degraded Visual Environments impact on the sensory systems
- Why learning about SD is important
  - Statistics – *USHST Spatial Disorientation Induced by a Degraded Visual Environment Training and Decision-Making Solutions Recommend Practice*
    - Avg. Total Flight Hours: 2,673
    - Avg. Total RW Hours: 2,161
    - Avg. Total Hours Make & Model: 609
    - The same top three primary occurrence categories routinely make up roughly 50% of fatal rotorcraft accidents.
      - Loss of Control – Inflight (LOC-I), Unintended Flight in IMC (UMIC), and Low Altitude Operations (LALT).
      - While SD is difficult to confirm in these accidents, it is likely an influence in many, particularly as a precursor condition to LOC-I.
  - Differentiation between Illusions and SD
    - Spatial Disorientation is a broad term often used incorrectly to describe a multitude of illusions a pilot may experience. Illusions can lead to Spatial Disorientation, an illusion itself does not always constitute Spatial Disorientation. Pilots often discuss experiencing illusions during normal instrument flight. For example, a pilot might experience the leans when entering a cloud bank in a turn. Because the focus is on the instruments, they become aware of the illusion the body is experiencing but have not experienced full onset SPATIAL DISORIENTATION. This difference is critical to understand as training methods are implemented.

2. Orientation In Flight ("Pilot Speak" vs. Doc Speak)

Overview: General overview of the human system

- Visual system
  - The visual system is the most dominant of the sensory systems. Through the eyes a pilot receives the vast majority (approx. 80-85%) of their orientation. The visual system is very reliable when a visible horizon is present but can lead to illusions during low visibility/low contrast conditions.
- Visual References – Visibility estimation in a dynamic environment
  - Comparative size of known objects
  - Comparative form or shape of known objects
  - Relative velocity of images moving across the visible field
  - Comparative location of landmarks
  - Over the nose of the aircraft, the point on the ground that you can barely see over the nose as it disappears is about the same distance ahead as your aircraft is above the ground – *AOPA Basic VFR How To Know It When You See It*
- Good spatial orientation relies on the effective perception, integration and interpretation of visual, vestibular (organs of equilibrium located in the inner ear) and proprioceptive (receptor located in the skin, muscles, tendons, and joints) sensory information. – *FAA Spatial Disorientation Pamphlet*
- Early and frequent instrument scan prior to and during Degraded Visual Environment flight conditions will help prevent the development of illusions and Spatial Disorientation.
  - Attitude
  - Altitude
  - Airspeed

3. Conditions Conducive to Spatial Disorientation in Degraded Visual Environments

Overview: Recognizing conditions that lead to SD in an effort to prevent the onset of SD

- Adverse Weather
  - Low visibility
    - Fog
    - Rain
    - Mist
    - Haze
    - Dust
    - Snow
    - Smoke
  - Low ceilings
- Low Contrast Conditions
  - Sunrise/Sunset
  - Moonrise/Moonset
  - Smooth/Glassy water
  - Low illumination – NVG
  - Lack of cultural lighting
  - Confusion of ground lights with starlight
  - Night unaided
- Local Weather Phenomenon

- Transitioning between IMC and VMC and vice versa
  - Entering low visibility conditions during “break out”
  - Head position; Instruments, approach plate, scan for landing environment conducive to vestibular disorientation
  - Transition period (VMC – IMC and IMC – VMC) poses the highest risk period
  - Transition to NVG; Techniques and challenges

4. Pilot Illusions

Overview: Raw explanation of the terms and illusions

- Visual Illusions
  - False Horizons
  - Confusion with Ground Lights
  - Brownout
  - Whiteout
  - Flat Light
  - Black Hole
- Vestibular illusions
  - Somatogyral
    - Leans
    - Graveyard Spiral
  - Somatogravic
    - Elevator
    - Oculogravic
    - Inversion
- Differentiate between Illusions and SD
  - Illusions – Something deceives or misleads intellectually
  - Spatial Disorientation – Caused by illusions that lead to an inability to maintain our body orientation and/ or posture in relation to the surrounding environment at rest and during motion
- Sensory Interactions leading to Cognitive Confusion
  - Occurs during high stress
  - Visual and Vestibular systems provide conflicting information
  - Contrary to normal conditions the visual system might not provide the primary source of orientation
  - Cognitive Confusion leads to incorrect flight control inputs or incorrect interpretation of aircraft condition and movement

5. Spatial Disorientation and Threat and Error Management

Overview: Managing SD

- Recognition, Avoidance, and Recovery Techniques
  - Flight Planning
    - Flight Activity Analysis
    - Weather Brief
    - Route Planning
    - Enroute Decision Trigger
      - Caution
      - Warning
    - Risk Analysis
    - Crew/Passenger Brief
  - Enroute
    - Enroute Decision Trigger Execution
    - Visibility estimation
  - Recovery
    - Power - Set cruise power
    - Attitude – Wings level, nose on the horizon
    - Balance – In trim
- Tools and Technologies to manage SD (Single vs. Dual Pilot situations)
  - Automation
  - Digital Co-Pilot
  - Crew Resource Management
  - Scenario-Based Training
- Human Stress factors/Planned continuation bias

6. Real World Examples of SD

Overview: Select accidents relevant to your operating environment

- Calabasas, CA – January 2020 (Links to reports)
  - VIP movement
  - Planned continuation bias
  - Use of automation
- Brainerd, MN – June 2019
  - HAA
  - IMC to VMC during IFR Approach
  - Planning vs Execution while in clouds
- New York NY – June 2019
  - Reposition
  - VFR only pilot
  - Overwhelming disorientation flying back into IMC conditions
  - Outside pressure to reposition aircraft

Flight Training Segment

Below is intended to be a general overview of practical training for Spatial Disorientation (SD). These topics are what the ACT ARC determined should be covered for flight training. Organizations should adapt the outline as necessary to address the operational aspects of their environment. The flight training is broken down into two modules: Maneuver-Based Training (MBT) and Scenario-Based Training (SBT). The MBT is designed as a precursor to the SBT. The ACT ARC believes that the SBT Module provides a significantly enhanced training experience and should not be excluded from any training program.

The selected training device will add to or limit the effectiveness of the training (*i.e.* hoods and foggles are not effective for visual illusions). Consider the value added by a particular training device.

Maneuver-Based Training Module

Maneuver-Based Training (MBT) is training that focuses on a single event or maneuver in isolation. The ACT ARC recommends that MBT include training under the highest workload environment for your operation (*e.g.* NVGs). The information below and contained in Table "Main Table" should be used to guide your MBT training.

1. Demonstrate distance estimation as it relates to deteriorating visibility, night, or other operational conditions experienced
    a. This demonstration can be in conjunction with visibility demonstration below
2. Demonstrate visibility of 5 SM and less
    a. Visibility changes should be communicated prior to the change to reduce potential for SD development
3. Demonstrate select illusions as listed in Table "Main Table"
    a. Illusions and spatial disorientation are unique to each situation and individual, the desired illusions might not always occur
    b. If the desired illusion did not occur discussion should include what illusions did occur, techniques used to prevent (intentional or unintentional) and reinforce the dynamic nature of each encounter with conditions conducive to illusions and SD
4. VMC Instrument Scanning Techniques
    a. Not an instrument scan
    b. Should be quick checks of critical instruments – Attitude, Airspeed, Altitude
    c. Primary focus should remain outside if the pilot has not transitioned to instruments – Each scan might only include a "peek" at single instrument as opposed to a standard IMC scan
5. Use of Automation
    a. How to setup aircraft automation/systems prior to degraded visual environments (*i.e.* stability systems, flight director, coupled autopilot)
6. Flight by Reference to Instruments

    Note: Focus should be on the transition to instruments. The transition period has historically caused SD accidents not established instrument flight. If a pilot loses visual reference to the horizon, they must be able to fly by reference to instrument; however, a training program should not focus primarily on flight by instrument to prevent DVE induced SD accidents.

   a. Using instruments in IMC
   b. Differs from VMC instrument scan
   c. Should include an approach
7. Application of Enroute Decision Triggers
   a. Triggers and execution use should be prebriefed
   b. When simulating the execution of an EDT, discussion should include all aspects of the execution (*i.e.* where to land, hazards during off airport landings, obstacles, nearest IMC recovery airport, nearest VMC recovery airport)
   c. Training can include continuation of the DVE to develop SD
      i. After discussion of how the EDT would be executed brief the pilot that the flight is continuing only for the spatial disorientation training
8. Recovery techniques for SD
   a. Power, Attitude and Balance can be used for an initial climb into IMC conditions or a technique for recovery. Aircraft weight, power limits and terrain should be considered during the Enroute Decision Trigger plan and brief.
      i. Power – Set power to cruise power
         1. Power should not be a “High Power” setting, initiating a high climb rate can lead to an elevator illusion causing pilot to pitch forward as a result
         2. Training of this power setting will aid in the immediate response – muscle memory
         3. Once power is set limit power adjustment – this reduces the scan workload on the initial entry/recovery phase
      ii. Attitude – Level wings, nose on the horizon
         1. The intent is to prevent descending and initiate a positive climb rate
         2. Consideration for known obstacles
      iii. Balance – Aircraft in trim
      iv. Transition to IMC scan and approach
         1. When an aircraft has entered IMC conditions conduct an instrument approach to transition out of IMC conditions – This is the case for IFR or VFR aircraft that have committed to IMC flight
9. Takeoff/Landing Considerations – Based on operational environment
   - Dust
   - Snow
   - Black Hole Effect

<u>Scenario-Based Training (SBT) Module</u>

Scenario-Based Training (SBT) is training that incorporates maneuvers into real-world experiences to cultivate practical flying skills in an operational environment. The ACT ARC recommends that SBT be trained under the highest workload environment for your operation (*e.g.* NVGs). The information below contains some practical examples that can be incorporated into your training program. Example scenarios can be found in Appendix “Y.” Developing specific scenarios based on your operational environment are highly encouraged.

Scenario Based Training Common Considerations

- **In-Aircraft:**
  - With Safety Considerations:
    - Safety pilot should remain focused outside on the safe operation of the aircraft.
    - If safety pilot has crew duties, CRM is critical to safe flight while training pilot is in a Degraded Visual Environment.
- **Ground Device:**
- **Training Considerations:**
  - Scenarios should be modified to replicate anticipated flight profiles.
  - Desired end state
    - Allow pilot to execute Enroute Decision Trigger (EDT)
      - If landing is determined to be the course of action discussion should include off airport landing zone considerations.
      - If intentional climb into the clouds is determined to be the course of action ensure pilot preps the aircraft for the climb.
      - If turn to known good weather is the course of action, discussion should include how the known good weather is determined.
      - If pilot does not execute EDT debrief must include discussion and training on Aeronautical Decision Making.
    - Instrument Recovery
      - If flight continues to IFR, recovery should be using an instrument approach.
- **Preflight Considerations:**
  - Preflight should include standard briefing practices.
  - If pilot does must brief EDT plan to include triggers and actions.
  - Safety pilot should brief if their role is as a safety pilot only or includes crew duties.
- **Post Flight Considerations:**
  - What EDT was used and why?
  - What other EDTs did the pilot have planned? Why were those

	not chosen? o If no EDT was used why not? o How long after the EDT did the pilot execute the adjusted plan? o Was full Spatial Disorientation experienced? ▪ Yes • Approximately what visibility when encountered? • What visual illusions were experienced? • What vestibular illusions where experienced? • Any other illusions? • Explain flying the aircraft during the disorientation? ▪ No • Did any illusions develop? • Discuss each encounter is different, each person is different.

1. Aircraft Dropoff Flight	
	• **Scenario:** o Reposition aircraft from current location to ________ for required maintenance. o METAR: KAAA DDHHMMZ 16006KT 4SM -RA BR FEW028 BKN037 OVC050 22/21 A2992 RMK AO2 o TAF: KAAA DDHHMMZ 0118/0218 23013G20KT P6SM BKN020 TEMPO DDHH/DDHH 3SM SHRA FMDDHHMM 27013KT P6SM BKN030 FMDDHHMM 31011KT P6SM SCT030 BKN050 o Aircraft must be delivered prior to end of duty day to begin required maintenance. Vehicle will be waiting at maintenance facility prior to arrival. • **Flight Scenario Setup:** o Using a predetermined point along route, program the system to begin the visibility degradation at that point. o Point should be along route, within 2 miles of exiting surface-based airspace. o Minimum visibility should be programmed to approximately 1.0-1.5SM below organizational minimums.

2. Law Enforcement

- **Scenario:**
    - Support for surveillance requested depart current location to ________ in order to provide surveillance support.
    - METAR: KAAA DDHHMMZ 16006KT 4SM -RA BR FEW028 BKN037 OVC050 22/21 A2992 RMK AO2
    - TAF: KAAA DDHHMMZ 0118/0218 23013G20KT P6SM BKN020
      TEMPO DDHH/DDHH 3SM SHRA
      FMDDHHMM 27013KT P6SM BKN030
      FMDDHHMM 31011KT P6SM SCT030 BKN050
    - Plan to track suspect vehicle if they depart location.

- **Flight Scenario Setup:**
    - Upon arrival at the location visibility should begin to decrease.
    - Find a vehicle to use as a "target" vehicle.
    - Minimum visibility should be programmed to approximately 1.0-1.5SM below organizational minimums.

- **Additional Considerations:**
    - If flight includes FO training should include how the FO can enhance the SA of the flying pilot.
    - Scenario can be modified to be a search instead of surveillance.