Spatial Disorientation Scenarios for the AW159 Helicopter Within a Synthetic Training Environment

Alaistair J. R. Bushby; Steven J. Gaydos

BACKGROUND: Spatial disorientation (SD) remains a stubborn and formidable challenge among rotary wing (RW) aircrews, particularly during times of high workload and deceptive visual cues. With tri-Service agreement, British RW Forces employ a layered training approach that now includes simulator-based immersive scenarios.

METHODS: Ten bespoke RW SD training scenarios were developed for the AW159 Wildcat helicopter simulator by a multidisciplinary team. Scenarios were embedded within advanced training packages that were not solely focused on SD. A voluntary, anonymous survey instrument was distributed post-SD sortie to assess hazard awareness, training effectiveness, role and mission relevance, and perceived ability to respond to future SD threat. A corresponding assessment from the simulator instructor was used for independent determination if the crew became disoriented during the training.

RESULTS: Over a 6-mo training cycle, 69 surveys were completed. Seven-point Likert-scale assessments yielded elevated median scores (6.0, respectively) across all four categories, suggesting favorable aircrew perceptions of training objective success. Elevated scoring of previous SD training received suggests good penetrance among the RW community surveyed. Of all sorties flown, the majority of aircrew (68%) became disoriented at some point during the sortie.

DISCUSSION: This report provides limited evidence in support of bespoke SD training scenarios within a synthetic training environment. The merits include flexible ability to address root causes, provision of an interactive and immersive environment, and compatibility with extant tactics and mission configurations. SD simulator-based training can serve as an important component of a layered, multimodal approach.

KEYWORDS: spatial disorientation, rotary wing, pilot training, simulator.

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"The practical problem remains as to how the subject should be taught and demonstrated to each successive generation of pilots to forewarn them and maintain their awareness of the potential dangers of disorientation in flight."[26]

Spatial disorientation (SD) has remained a constant and formidable challenge to aircrew safety and operational effectiveness for decades. SD is defined as "…a variety of incidents occurring in flight in which the pilot fails to sense correctly the position, motion, or attitude of the aircraft or themselves within the fixed coordinate system provided by the surface of the Earth and the gravitational vertical" (p. 281).[27] A close companion of pilots since the very beginning of aviation, the far-reaching impact of SD has been described for well over a century. One young World War I aeromedical physician commented "…it has even been recorded that some have flown upside down without knowing it" (p. 33).[2] Despite its critical relevance to safe aviation operations, the aeromedical community still has more to learn regarding the complex interactions

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between human sensory systems, the dynamic force environments of flight, and spatial orientation. However, it remains certain that SD contributes to numerous fatalities, aircraft loss, and operational degradation.[11,12,26]

Within the British military rotary wing (RW) community, SD remains a causal or contributory factor in about one-third of serious accidents and carries a disproportionate penalty with respect to fatality rates when compared to non-SD accidents.[1,5] In one recent survey, the United Kingdom (UK) military SD incident rate per flying hours was higher for RW than other aircraft types (twice that of fast-jet), with greatest numbers among Apache and Wildcat airframes.[14] With the operational requirement to fly increasingly complex platforms within more challenging environments (e.g., degraded visual environments [DVE], low-level terrain flight, complex mission sets, and nonpermissive tactical airspace), SD remains among the greatest physiological threats to RW aircrew.[3,9]

Previous reviews of UK RW SD accidents have established that inattention (36%) or visual misinformation (33%) are of major provenance, with only a minority (11%) categorized as vestibular in nature.[5] Subsequent review and recommendations have included a need to focus limited training resources toward areas of highest risk, including recognizing incipient SD at times of high workload or deceptive visual cues (historically, there has been too great an emphasis on traditional vestibular illusions with limited relevance to RW operations). Other recommendations were directed at employment of contextual and interactive learning [whereby crews are able to make decisions and fly themselves into a relevant and risky situation incorporating workload, crew resource management (CRM), and relevant flying environments].[3,5]

With this review, extant SD training, while fully compliant with STANAG 3114 requirements, was found to be deficient in addressing root causes and judged insufficient in influencing future SD incidents and accidents.[3,22] In order to address these shortcomings, the UK Consultant Advisors in Aviation Medicine endorsed a tri-Service, layered approach in 2016: 1) SD instruction for RW pilots begins with initial aviation medicine training that includes classroom academics and disorientation simulation prior to basic flying training; 2) in-flight SD demonstration is provided within basic flying training; and 3) refresher training using interactive synthetics or in-flight demonstration is then provided at least once every 5 yr, in accordance with advanced airframe capabilities and training systems.

The AW159 Wildcat is capable of carrying troops and equipment as a utility helicopter; however, the main role of the aircraft is reconnaissance. For this airframe, SD training continues within a high-fidelity synthetic training environment with bespoke scenarios designed to set preconditions and contribute to aircrew disorientation. Scenario development for sorties was specifically directed at known RW SD challenges, including DVE, lost or sloping horizons, poor or deceptive ambient or cultural lighting, featureless or sloping terrain, misleading altitude cues, and subthreshold drift. Many are delivered within a context of high workload and system-intensive mission requirements, while using constituted crews. However, despite investment in resources, the effectiveness of these scenarios in achieving objectives within a synthetic training environment (as part of a comprehensive SD mitigation strategy) is unknown. Previous survey instruments have been employed to help assess and shape SD-specific training.[15,18,23] Given these circumstances, a brief aircrew survey was developed with interest in: 1) overall appreciation of SD as an important contributor to aviation incidents and accidents; and 2) specifically within scenarios, the ability of the training to personally increase awareness of SD hazards—while remaining relevant to role and experience—and prepare crews for future SD incidents. The survey instrument was consciously employed with appreciation for limited aircrew time and minimal disruption to training progression and throughput.

METHODS

Ten bespoke RW SD training scenarios were developed for the AW159 Wildcat helicopter simulator as depicted (in no particular order) in **Table I**. A voluntary, noninvasive, anonymous Likert-scale survey instrument was distributed to Wildcat pilots post-sortie in order to assess training effectiveness, role and mission relevance, and operator consonance regarding training scenarios. The service audit was determined exempt via Joint Service Publication regarding governance of research. Scenario packages were intentionally embedded within other routine simulator training requirements focused on non-SD training objectives so that crews were not necessarily anticipating SD or solely focused on an expected or pending SD situation. These advanced environmental training packages, which included the SD scenarios, were delivered biannually, and Wildcat aircrew experienced between one to three scenarios during the training period, depending on circumstances and package. Debriefing was conducted at the conclusion of training iterations by the simulator instructor.

Self-reported experience (total flight hours and hours on type) and range of previous SD training received, as well as personal historical experience with a significant or severe SD incident, were solicited. Succinct training assessments were focused on four key questions with 7-point Likert-scale assessment (**Table II**).

A corresponding but separate assessment from the simulator instructor was used to determine if the crew did (Y/N) become disoriented during the sortie. Both aircrew and simulator operator were permitted generous freeform comments if they elected to do so. Data management and statistical analysis were completed with Microsoft Excel®, MSO ver. 2018. Data collection was conducted at the Wildcat Training Centre simulator complex and consisted of a 6-mo calendar period, which corresponded to a standard training cycle for the advanced sortie simulator training package.

Table I. Ten SD Training Sorties.

SCENARIO	COMMENTS
Dust departure	Out of ground effect takeoff with obstacles in DVE* dust recirculation, false cueing, and high operating power limits; considerably increased workload leading to saturation.
Snow-laden valley	Lack of visual horizon and homogeneous scene with blowing snow and misleading altitude cues; increased urgency with immediate casualty evacuation.
Deck departure	Maritime scenario with lateral hover to takeoff; low ambient light, limited altitude cues and featureless overwater terrain; minor malfunction increases workload and distraction.
Brownout approach	Approach to hover over dust-laden unfamiliar landing zone, reduced visual references, recirculation, and false cueing; high workload and limited altitude cues.
NATO† T approach	Incorrectly positioned NATO-T on sloping ground causing poor assessment of approach angle; crosswind component increases workload; low ambient and environmental lighting with terrain create black hole conditions.
Deck landing	Combination of poor ambient light and lack of discernible horizon; wake turbulence and high workload conditions with featureless overwater terrain.
NVD‡ low level transit	Nap-of-earth NVD flight; combination of poor ambient light conditions, lack of discernible horizon, and snow-covered terrain leading to hidden ridges and late warning of terrain.
NVD formation	Low level NVD join formation task converging with lead aircraft; clear skies over water with environmental lighting on horizon causing loss of visual with lead.
Desert Box	Landing Desert Box laid out to incorrect size (inexperienced ground troops) resulting in a high closure rate and late identification of the issue; poor ambient lighting and increased urgency with immediate casualty evacuation.
Deck recovery	Low ambient light conditions with lack of discernible horizon to join downwind; wake turbulence and high workload conditions with featureless overwater terrain.

*DVE: degraded visual environment; †NATO: North Atlantic Treaty Organization (also called the North Atlantic Alliance); ‡NVD: night vision device.

RESULTS

Over the 6-mo training cycle, 69 surveys were completed (zero participation declinations via anonymous submission of a blank survey). Self-reported flying experience (rounded to nearest 100) included median Total Flying Hours (TFH) of 1300 (range: 300, 6700, SD = 1423.7) and median Flying Hours on Type (FHOT) of 500 (range: 100, 2000, SD = 508.5). Previous forms of SD-related instruction for aircrew included lecture (90%), disorientation trainer (90%), in-flight SD demonstration (81%), and any type of previous simulator scenario-based training (74%). Range of previous SD training received was scored with 1 point per category (0–4), producing a median of 4.0 (range: 1, 4, SD = 0.92). Results are depicted in **Fig. 1**. A minority of aircrew (31%) reported that they had previously experienced an actual major in-flight SD incident defined as either significant ("could have been nasty") or severe ("lucky to get away with it"). Using a median split for TFH (four non responses), there was no significant relationship between high/low experience cohorts ($\chi^2(1,65) = 2.34$, $P = 0.12$) and having had a major in-flight SD incident.

Pearson correlations were used to assess interrelationships among variables (**Table III**). There exists a strong positive relationship between TFH and FHOT [$r(67) = 0.77$, $P < 0.001$]. There also exists a strong positive relationship between questions Q2, Q3, and Q4 as follows: Q2 and Q3, $r(67) = 0.66$, $P < 0.001$; Q2 and Q4, $r(67) = 0.75$, $P < 0.001$; Q3 and Q4, $r(67) = 0.77$, $P < 0.001$. Likert-scale pilot ratings for the SD scenarios are depicted in **Fig. 2**.

Of all sorties flown, the majority of aircrew (68%) became disoriented at some point during the sortie as reported independently by the simulator instructor (three nonresponses). Using a median split, there was no significant relationship between high/low experience cohorts for TFH [$\chi^2(1,66) = 0.29$, $P = 0.59$] or FHOT [$\chi^2(1,66) = 0.76$, $P = 0.38$] and disorientation during the SD training sortie. Generous freeform comment sections were provided to both aircrew and simulator instructors. Of all survey returns, the majority (72%) elected not to provide comments. Of those received, two-thirds were generally grouped as favorable or supportive of scenario training experience. Of comments received, the majority were directed to the specific scenario received that may prove helpful

Table II. Post SD Sortie Pilot Ratings (Likert Scale, 1-7).

POST SD SORTIE PILOT RATINGS						
Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree
1	2	3	4	5	6	7
Q1. OVERALL, to what extent do you believe that SD is an important contributor to aviation incidents or accidents?						
Q2. Given your sortie TODAY, to what extent do you believe the scenario was relevant to your role and experience in presenting conditions consistent with possible SD?						
Q3. Given your sortie TODAY, to what extent do you believe the training raised your awareness for potential SD hazards with respect to weather, mission planning or sortie execution?						
Q4. Given your sortie TODAY, to what extent do you believe the training prepared you for a potential SD incident and how you may prevent, mitigate or respond to the hazard?						

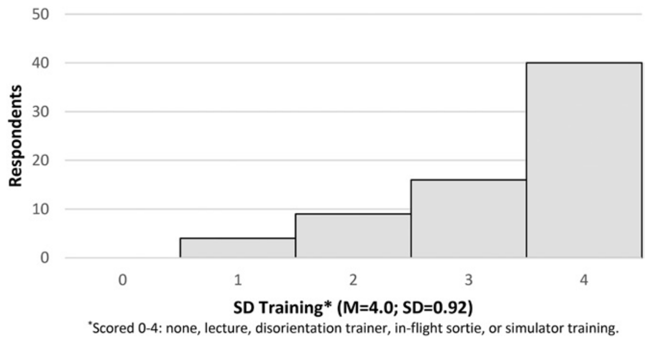

Fig. 1. Range of spatial disorientation training (M = median; SD = standard deviation).

for iterative improvements. The survey was well-received by aircrew with appreciation for its concise nature.

DISCUSSION

The late Malcolm Braithwaite, a pioneer of the British Army RW in-flight SD training sortie, simplified the SD antivenom: "Countermeasures to SD primarily fall into two categories: technology and training."[24] He was also careful to parse differences between instruction, demonstration, and training: training brings not only information and the provision of evidence but "…a desired state of efficiency or condition of behavior…" Regarding technology, there have been significant advances including novel visual displays, ground proximity warning/recovery systems, "see through" DVE technology, tactile feedback, automation, and others. However, many have historically argued for the importance and priority of aircrew training as well.[4,6,13] The answer, of course, is both—delivered within a layered, complementary, experience-appropriate, and mission-specific package longitudinally throughout the aviator's career. With his insightful commentary almost a decade ago, Cheung laid out many of the significant issues and challenges with respect to SD understanding and training, and several of the tenets employed within this particular training paradigm correspond with his 10-point "wide-angle" holistic approach.[7]

Successful SD simulator-based training has been described previously.[10,15,28] Regarding this specific package, the Wildcat AW159 synthetic training sorties were judged to be efficacious by the aircrew themselves. Elevated median Likert scores for all category assessments reflect the high quality of the training sorties for hazard awareness, relevance to role and experience, and preparatory mitigation (Fig. 2). The fact that the scenarios were specifically designed to present known or historical SD challenges—including DVE, lost or sloping horizons, poor or deceptive ambient or cultural lighting, featureless or sloping terrain, misleading altitude cues, and subthreshold drift—to RW aircrew is thought to be partly responsible for this success. Interestingly, these also largely corresponded with the top SD experiences for RW transport (nonattack) platforms reported by Pennings et al., which included sloping horizon, undetected drift, lack of altitude cues due to featureless terrain, loss of horizon due to sand/snow, and misleading altitude cues.[23] The addition of scenario components such as a mission imperative (e.g., pickup of deteriorating casualty), workload (e.g., operating at edges of aircraft performance), and distraction (e.g., aircraft system malfunction) was also thought to contribute toward achievement of objectives. The inclusion of this overlying patina can be important in some instances as Stott has previously noted, "Many pilots have commented on how quickly a flight trajectory can go from safe to unsafe when attention is diverted away from the flying task. This is particularly true when the aircraft is maneuvering at low level."[26]

In the early stages of scenario development, two factors were judged to be important: 1) employment of a bona fide cross-pollination development team and 2) embedding SD scenarios within regular non-SD training iterations. Scenarios were developed with multidisciplinary input including specialists in aviation medicine, qualified aircrew instructors, and simulator instructors and technicians. Each brought various competencies, differing experience, and diverse perspectives. Initial development was drawn from real-world experiences (both incidents and accidents) and the designed scenarios

Table III. Descriptive Statistics and Correlations.

		PEARSON CORRELATIONS								
		M	SD	1	2	3	4	5	6	7
1	Total flying hours**	1300.0	1423.7	–						
2	Hours on type**	500.0	508.5	0.77*	–					
3	Range of previous SD training†	4.0	0.92	0.20	0.22	–				
4	SD important contributor to mishaps (Q1) ‡	6.0	1.1	-0.16	-0.18	-0.11	–			
5	SD training relevant to role or experience (Q2) ‡	6.0	1.2	-0.17	-0.14	-0.02	0.36*	–		
6	SD training increased awareness of hazards (Q3) ‡	6.0	1.1	-0.16	-0.14	0.04	0.18	0.66*	–	
7	SD training prepared you for potential SD incident (Q4) ‡	6.0	1.1	-0.13	-0.10	0.02	0.31*	0.75*	0.77*	–

Column numbers correspond to numbered variables in rows.
M = median; SD = standard deviation.
*$P < 0.05$; **self-reported flying experience (requested to round to 100 s); †scored 0-4 including none, lecture, disorientation trainer, in-flight sortie, or simulator training;
‡Likert scale 1-7.

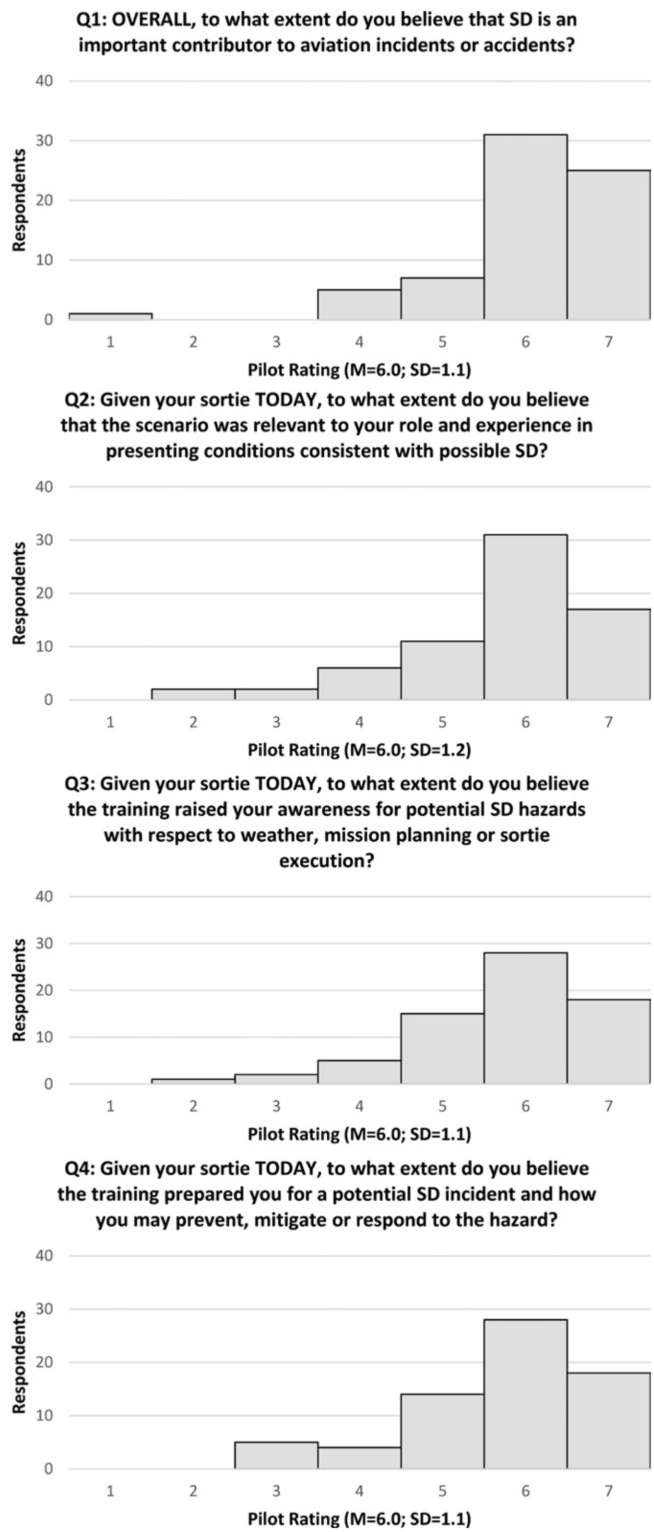

Fig. 2. Likert-scale pilot ratings, Q1 – Q4 (M = median; SD = standard deviation). See Table II for Likert-scale assessment.

were flown in several permutations in order to make iterative improvements. This approach also served to help "de-medicalize" SD. Too often senior leadership and aircrew themselves view the issue solely through a medical aperture; in reality, SD is a command problem, an operator threat, and a safety issue requiring "whole-of-team" investiture and engagement. Encouraging and empowering nonmedical stakeholders within the aviation community to "take ownership of SD" is imperative for that whole team effort.

Secondly, to prevent anticipatory contemplation, the SD training was purposefully embedded within other routine simulator training requirements focused on non-SD training objectives. This required aircrew to understand the SD-related preconditions during the pre-mission phase, appreciate the impact of evolving meteorological conditions or dynamic re-tasking, and react to orientation threats appropriately with CRM and decisive mitigating action.

Within the UK tri-Service layered training approach, the majority of aircrew reported receiving all forms of training, which suggests favorable penetrance. Only about one-third of respondents self-reported an actual in-flight SD incident previously. However, note that this was specifically circumscribed to include only a significant ("could have been nasty") or severe ("lucky to get away with it") event. There was no statistically significant relationship between pilot experience (high and low time cohorts) and report of such a major SD incident, which suggests that all pilots remain at significant risk.

With respect to the training sorties evaluated, two-thirds of aircrew became disoriented at some point during the sortie, as reported independently by the simulator instructor. Interestingly, there was no significant relationship between experience (high/low time TFH and FHOT groups) and becoming disoriented. This may initially appear contrary to expectations, since experienced pilots might be expected to make better decisions to avoid disorientation. However, crews are usually rostered with a high time experienced aircraft commander (pilot-in-command) and a more junior copilot, which likely had a balancing effect. Furthermore, note that the intent of the training was not necessarily to obligate the crew to disorientation, but rather to set preconditions and then allow aircrew "training space" for risk assessment, decision-making, and execution of mitigation measures. Some comments were illustrative of a difference in how training success was perceived. As an example, a very junior aviator commented, "I experienced SD in the sim so it's working!" In contrast, a more senior pilot commented, "Most of the scenarios I would not put myself in that situation. However, this is a good opportunity to raise awareness to pilots that all can go wrong quickly and horribly if your choices/decisions are questionable."

With the intent of understanding aircrew assessment of the effectiveness of the synthetic training environment, this survey methodology is subject to several limitations. Bias cannot be discounted, including: social desirability (self-portrayal within a favorable light), central tendency (avoidance of extremes in ratings), and acquiescence (desire to agree).[8] However, it should be noted that aircrew have a vested interest in critical feedback to improve the quality of their training (note zero declinations to complete the survey). Surveys were completely anonymous, voluntary, and without any penalty or untoward effect based on the rankings, comments, or decision to complete. Survey length was intentionally kept short to minimize effort of attention. Careless response and response inconsistency are also a concern regarding survey methodology in general. Studies of bogus responding have demonstrated that this can be substantial (3–46%).[19–21] However, when it comes to the potential to influence real decisions regarding training or policy, it is reassuring that a recent large study of careless survey response among the U.S. military demonstrated that populations remained sufficiently engaged, with incorrect bogus responding very low (< 5%).[25] The 6-mo window of data collection generally corresponded with a standard training cycle for the advanced sortie simulator training package, affording the best opportunity to sample all pilots in the training cycle without duplication. However, response anonymity prevented certainty that all pilots were sampled or that there were zero cases of repetition. Increased survey numbers would certainly be desirable; however, this was balanced with the endeavor for minimal disruption to aircrew training progression and throughput. Lastly, self-reported data in general relies upon honesty (social acceptability versus truthfulness), as well as introspective ability (accurate self-judgement).

Clearly, RW SD continues to present a significant flight safety risk for military aircrew.[11,12,26] For the UK military RW community specifically, this has been highlighted previously[16,17] and was again just this year within a tri-Service survey of UK aircrew SD incidents.[14] In that latest report, the authors singled out the unique differences for RW incidents, noting the importance of training that caters to those differing experiences versus other aircraft types. Consistent with that recommendation, and as part of a complementary and layered approach to training and mitigation, these survey results suggest that the bespoke Wildcat simulator sorties were successful in achieving desired SD training objectives. These results also align with the most recent UK RW SD survey whereby three-quarters of respondents reported that SD training was advantageous (indicating "useful" or "essential").[14]

Within a resource-constrained training environment and with ever-increasing aircraft operating costs, high-fidelity simulation will remain an important element of aircrew training in general. It remains relatively cost-effective, easily configurable, and safer. This report provides limited evidence in support of bespoke SD training scenarios for the AW159 Wildcat helicopter within a synthetic training environment. Demonstrated herewith, the merits of immersive synthetic scenarios include flexible ability to address root causes, provision of an interactive and immersive environment, and compatibility with extant tactics and mission configurations. While it may never deliver a single-source solution (classroom academics, dedicated disorientation trainers, in-flight demonstrations, and live aircraft environmental training are all impactful), SD mitigation simulator-based training can serve as an important component of a layered, multimodal approach.

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