Chapter 4 – IN-FLIGHT SD TRAINING

4.1 ROTARY WING IN-FLIGHT DEMONSTRATION OF SD ILLUSIONS

4.1.1 Introduction

This section concerns the demonstration of the limitations of the orientation senses in flight, especially those of the vestibular system and the 'seat-of-the-pants'. Demonstrating the limitations of the human equilibrium system in the aviation environment has a distinct advantage above the demonstration in ground-based devices, since it concerns the real aircraft motion. This makes it also more convincing for experienced pilots for the refresher courses, because it is the environment in which they operate. Assessment of the rotary-wing version of this SD demonstration in the British and American Armies has shown that aircrew's "awareness" of the limitations of the orientation senses is greatly enhanced. It also saves lives and money: The British Army Air Corps experienced a 75% reduction in the SD accident rate, since instituting this enhanced awareness training in helicopters [25].

There is good evidence from the British Army Air Corps' experience that the sortie is best initially flown just before students learn instrument flying in helicopters. In order to aid understanding and awareness, the period since students have attended aeromedical lectures on SD should not be too long. Although this evidence holds for student-pilots for helicopters, it is reasonable to assume that the same holds true for FW student-pilots.

The illusions to be described occur in real flight particularly in total darkness or in conditions of poor visibility. This is realized by the subject student-pilot having his eyes closed during the demonstration. In the forward flight maneuvers he is instructed to close his eyes when the helicopter has reached the described forward air speed at the requested altitude. This holds for all the demonstrations described in this section, and will therefore not be repeated in the description of each separate illusion.

4.1.2 Examples of Rotary-Wing SD Demonstration Maneuvers

During the RW-demonstrations the student-pilots are always passengers. One is subject of a particular demonstration, who reports about his orientation, while the others are observers. Their role changes such that everybody has played both roles sufficiently.

There are basically five maneuvers, four of which start with a forward flight, and one that starts from hover. A short description of these maneuvers and the essential debriefing is giving below.

4.1.2.1 Level Turn

From straight and level flight a coordinated turn is executed while maintaining airspeed and altitude. The response of the subject allows for discussion of the limitations of the semicircular canals in the debriefing.

4.1.2.2 Straight and Level

A straight and level flight is maintained for some time at 90 – 100 knots. Students report variable motion due to the turbulence and the aerodynamic response of the helicopter, which allows the debriefing about the effects of brief stimulation of the kinesthetic receptors and vestibular apparatus.

4.1.2.3 Straight and Level Deceleration

A deceleration from the initial 90 – 100 knots to less than 30 knots within 30 – 40 seconds during straight and level flight, without change of heading or altitude. Subject often reports a climb, allowing in the debriefing to discuss the absence of accurate physiological perception of airspeed.

4.1.2.4 Inadvertent Descent

The student closes his eyes while flying straight and level at 90 – 100 knots about 500 ft above ground level (AGL). While initiating a descent at below 500 feet per minute, a series of turns is commenced. The subject reports his heading, height, and airspeed, when the aircraft is established in flight below 50 feet AGL, and then opens his eyes. The descent is usually not perceived, which makes the point clear in the debriefing of the danger of inadvertent descent.

4.1.2.5 Hover

Demonstrations start from a 5- or 6-foot hover. Students are exposed to a variety of linear and rotational movements while maintaining hover height. Subject has to give a running commentary, which helps to exacerbate the onset of SD. Within these exercises various maneuvers are “hidden” so that when the student opens his eyes, a dramatic end point is evident: this may be either climbing backwards at 10 – 15 knots, landing without the subject realizing it, or a gentle transition to forward flight. Most aircrew are able to maintain their orientation for only 10 to 15 seconds. These exercises have a most educational effect upon the subject and observing students. In the debriefing the poor ability to detect linear movements is discussed, and the relevance of physiological orientation limitations in the context of snow, sand, and night operations is emphasized.

4.1.3 Organization

The Demonstration Procedures for the demonstrations just described would be ideal if three students are flown on each sortie. Each experiences one of the forward flight maneuvers and one of the hover maneuvers. Flying the sortie with three students is also the most cost-effective solution. The sortie should not be flown with less than 2 students, as there are distinct benefits from observing the reaction of peers as well as experiencing the maneuvers themselves.

During the transit to the demonstration area, the Flight Surgeon (FS) briefly revises the physiology of the orientation senses. A series of forward flight and hover maneuvers is then conducted. In turn, personnel are asked to sit free of the airframe structures other than the seat, note the aircraft’s initial flight parameters, close their eyes and lower their dark visor, and as the “subject” for that maneuver, to give a running commentary on their perception of the aircraft’s flight path. In this way, the “subject” is deprived of vision, the most important orientation sense, so that the limitations, particularly the unreliability of the non-visual orientation senses, could be demonstrated. The other two personnel (observers) are asked to observe but not comment until after the maneuver is complete. The FS then debriefs the individual maneuver. All students experience at least one maneuver in each of the forward flight and hover groups.

4.2 FIXED WING IN-FLIGHT DEMONSTRATION OF SD ILLUSIONS

4.2.1 Fixed Wing SD Demonstrations

The RAF designed a SD demonstration in Fixed Wing (FW) aircraft for high performance flight profiles in the Hawk [2]. The demonstration could be adapted for other high performance FW aircraft, whereas application of the principles for SD demonstrations in low performance or multi-engine aircraft is feasible, although some modifications may be required to get the desired effect. The power of the demonstrations is

that they consist of real flight profiles. The combination of somatogravic and somatogyral illusions convincingly illustrates how inaccurately human senses predict orientation relative to the earth's surface.

However, high-performance FW aircraft have a maximum of two seats. In contrast to the Rotary Wing (RW) SD demonstration, this FW SD demonstration must therefore be performed "one-to-one". This has consequences for the student: They can only play the role of subject, not of observer. As subject they realize their disorientation at the moment they open their eyes, but they have no cue as to how they reached that position. They therefore don't get an understanding for the development of the SD over time, something the observers in the RW SD demonstration learn by comparing the flight profile and the verbal report of the subject.

Nevertheless, the demonstrations are convincing since the stimuli are the real flight profiles. The effect of the demonstration is enhanced by giving the student control of the aircraft (still with the eyes closed), mostly with the instruction to fly straight and level. When he/she opens the eyes, the effect of the demonstration is pretty optimal. This procedure requires that the subject has at least some basic know-how about aircraft handling (10 – 15 lessons).

Eight SD maneuvers have been identified for the FW SD demonstration. All demonstrations start from flying straight and level at a certain height and speed. At that moment the subject is requested to close his eyes and the demonstration maneuvers start. The maneuvers are described in Section 4.2.2.

4.2.2 Examples of Fixed-Wing SD Demonstration Maneuvers According to AIR STD 61/117/13

The following examples have been developed for demonstration in high-performance aircraft [32,2]. In transport aircraft demos 4.2.2.2, 4.2.2.3, 4.2.2.4 and 4.2.2.5 were found to be very useful too; the other demos need slight modifications to induce the described illusions.

4.2.2.1 Pitch Misperception During Acceleration

The student is instructed to close his/her eyes. The IP accelerates the aircraft from 150 knots. The student is then asked to estimate the perceived pitch change. Alternatively he/she is given control of the aircraft (with eyes still closed) and instructed to maintain level flight. The result is either a perceived pitch up sensation or the student pushes the nose over if he has been given control.

Debriefing points: This illusion results from the linear acceleration acting on the otoliths of the inner ear. The resultant vector from the linear acceleration and normal gravity gives the sensation of an increase in pitch. Such a somatogravic illusion can occur in a phase of flight of sustained acceleration, such as on takeoff, particularly in afterburner or catapult launches. In order to overcome the sensation of an increasing pitch attitude, the pilot will pitch the nose down and, if not attentive to the actual aircraft attitude, will result in controlled flight into the terrain (CFIT).

4.2.2.2 Elevator Illusion

The student is instructed to close his eyes. The IP establishes a constant rate climb/descent and then levels off. The student is given control of the aircraft (with his eyes still closed) and instructed to maintain level flight. The result is that the student re-enters a climb or descent.

Debriefing points: This illusion can occur during a constant rate climb on a standard instrument departure (SID) with an intermediate level off, or during descent on an instrument approach with an intermediate level off. The pilot misperceives the resultant G vector associated with the pitch angle and, if not attending to the attitude indicator upon level off, will tend to resume the climb or descent to achieve the same

"seat-of-the-pants" feeling. At best the pilot will be violated for busting a hard altitude; at worst, a stall or CFIT will happen.

4.2.2.3 False Climb in a Turn

The student is instructed to close his eyes. The IP slowly (< 2 deg. sec2) achieves 45° AOB. The student is asked what attitude he/she perceives and is given control of the aircraft (with eyes still closed) and instructed to maintain level flight. The result is that the student perceives a climb, lowers the nose and descends.

Debriefing points: This is another somatogravic illusion that can subtly occur anytime during flight, in VMC or IMC, if the pilot is not attending to the actual aircraft attitude. If one unknowingly allows a sub threshold turn to occur, especially in level flight, the pilot will sense the increased G and, thinking that the aircraft is still wings level, will sense that the aircraft is climbing. The natural corrective control input would be to lower the nose. If operating at low altitude, the result would be disastrous.

4.2.2.4 Diving During Turn Recovery

The student is instructed to close his eyes. The IP sustains a 1.5 G turn and then recovers to straight and level flight. The student is asked for his/her perception of the aircraft's attitude during recovery. The result is that the student perceives a nose down pitch change with recovery to the 1G environment.

Debriefing points: This somatogravic illusion is opposite to the preceding one. In this case, the pilot is in a known sustained turn with the associated increase G level. If not attending to attitude and performance instruments, the pilot will sense the lesser 1G environment upon rollout and feel like the aircraft is descending. The tendency will be to raise the nose of the aircraft. This often occurs, for instance, when a student practicing steep turns climbs during turn reversal because of the decreased G passing through level flight.

4.2.2.5 The Somatogyral Illusion

The student is instructed to close his eyes. The IP conducts a 270 – 360° of turn at 30° AOB and then recovers to straight and level flight (at a supra-threshold rate). The student is asked to describe the aircraft's attitude. The result is that the student perceives a turn in opposite direction.

Debriefing points: Every instrument rated pilot has experienced this somatogyral illusion. During IMC flight, a suprathreshold roll in the opposite direction from an established turn (that feels like level flight) sets up the appropriate rotatory stimulus in the semicircular canals. Now the pilot feels the aircraft is in a turn in the opposite direction, even though the attitude indicator shows straight and level flight; hence, the leans.

4.2.2.6 Post Roll Effect

The student is instructed to close his eyes. The IP establishes 45° AOB, and then rolls 90° in the opposite direction. The student is given control of the aircraft (with his eyes still closed) and instructed to maintain the aircraft attitude. The result is that the student increases the roll and allows the nose to drop.

Debriefing points: This illusion, possibly prominent in several low-level CFIT accidents, is primarily somatogyral in origin, although there could be a somatogravic component. During roll reversal, the pilot can sense a roll in the opposite direction and compensate by increasing the roll in the direction of turn. If not attending to the real aircraft attitude while attempting to maintain the same "seat-of-the-pants" sensation, the pilot simultaneously allows the nose of the aircraft to drop. The increasing roll rate and

decreasing pitch attitude will result in an unusual attitude at cruising altitudes, and impact with terrain at low-level.

4.2.2.7 Tilt with Skid

The student is instructed to close his eyes. The IP puts in full rudder trim and then the student is asked to describe the aircraft's attitude. The result is that the student perceives a sensation of tilt.

Debriefing points: When cross-controlling an aircraft (admittedly rare in modern fast jets) a pilot could get a somatogyral input about the yaw axis that is interpreted as a tilt or perhaps a roll. The reaction would be to input controls to counter the perceived aircraft motion. This may happen when applying rudder to counter a crosswind condition. If in IMC, the pilot could enter an unusual attitude.

4.2.2.8 Coriolis Cross-Coupling Effect

With the student's eyes open, the IP performs at least four continuous aileron rolls. The student is then instructed to move his head out of the rotating plane (forwards or to one side). The result is that the student perceives a tumbling sensation.

Debriefing points: From the time that we entered pilot training, we have all been cautioned about moving our heads in the cockpit because of the Coriolis Effect. Although a rare occurrence during flight, continuous aileron rolls effectively induce somatogyral motion about the longitudinal axis. Once the pilot places his head out of plane, a tumbling sensation ensues, but is short-lived.

4.2.3 Organization

The originators of the demonstrations stress the point that no extra training sortie is required to perform this FW SD demonstration. The eight illusions can be flown in a total time of about 20 minutes. Alternatively, a few can be demonstrated on several sorties, either en route to a training area or returning to base. However, it is imperative that the training objectives be established.

For internal feedback and validation, a debrief form to be completed by students after the demonstration is very useful, both for RW and FW SD demonstrations. For larger air forces the ultimate value of this method of increasing the SD awareness of aircrew can be assessed by external validation in the reduction of the SD accident rate.

Whenever possible, a demonstration to further reinforce education in the limitations of the orientation senses in flight should be performed in a basic aircraft of the type to be flown by aircrew. This should be part of the initial training and repeated at regular intervals. It is desirable that this sortie is flown by a medical officer pilot (flight surgeon) in order to explain the mechanics of SD. In air forces without medical officer pilots, this task may be accomplished by specially trained flying instructors. Such demonstrations are best achieved with other students observing the subject.

4.3 IN-FLIGHT SD TRAINING SCENARIOS

In-flight SD training implies learning flying procedures that anticipate disorientating circumstances and coping with the illusions once they have been encountered. This is the remit of the flying instructor and should take place in both simulator and actual flying sorties in both initial military flying training and as part of regular continuation and aircraft conversion training. Spatial orientation is a component of the aviator's more comprehensive perception and appreciation of the tactical flight environment, which is referred to as situational awareness. Consequently, a pilot who has an erroneous perception of aircraft orientation also suffers from a loss of situation awareness, but loss of SA can occur for many different

reasons in the absence of any spatial disorientation. Obviously SA encompasses factors beyond the scope of this SD report and will not be treated in detail.

4.3.1 Management of SD in Flight

With present technology, training in the management of recognized (Type 2) SD is limited to recovery from unusual attitudes and action upon inadvertent entry to Instrument Meteorological Conditions (IMC) [2]. These topics must be established as training objectives and not merely demonstrations. Training will be aircraft type specific and, although some generic training may be possible on initial flying courses, further training will be required when a pilot first encounters different climatic or operational scenarios (e.g. helicopter snow landings). Therefore inclusion of these objectives in all pilot training courses is the minimum requirement, but further specification is not possible.

4.3.2 In-Flight Training

Learning and thence demonstrating competence in handling in-flight disorientating circumstances and illusions, e.g. recovery from unusual attitudes and procedures for inadvertent entry to IMC. This is the responsibility of flight instructors (who have themselves been appropriately trained to teach the procedures and assess competence).

Most modern air forces already incorporate some training of this sort described above. Standardization of the training objectives will be of great benefit in providing a common training base for aircrew on joint and combined operations, the goal being a commonality in experience and expertise. This is one of the goals of both NATO and the Air Standards Coordinating Committee (English-speaking nations).

SD Training should be conducted during both elementary and advanced (including operational conversion) flight training, and also during conversion to each specific aircraft type. An assessment of skills should also be made during revalidation of an instrument flying rating.

The following are considered the **minimum** requirements for which a training objective is to be stated [2].

4.3.3 Inadvertent Entry into IMC

Procedure: During a training flight in VMC, the instructor will announce a simulated inadvertent entry to IMC. If the aircraft is appropriately rated, the procedure is to be performed during both day and night flight. It will also be performed during flight with NVDs if the aircraft is appropriately equipped and the student rated on NVD.

Objective: The student will correctly perform the procedures for inadvertent entry to IMC, i.e. immediate reversion to flight by reference to the primary flight instruments. Indicated airspeed and vertical speed are to be appropriate to the aircraft type. A climb to the safety altitude is to be achieved.

4.3.4 Recovery from Unusual Attitudes

Procedure: During a training flight in simulated IMC (e.g. blackout screens/visors fitted to the aircraft/student) and with the instructor acting as safety pilot, the student is to be instructed to close his eyes while still on the controls. The safety pilot may release the automatic flight control system (AFCS) and stability/trim control to assist departure from the stable flight parameters. When the aircraft has significantly departed from stable flight (a significant departure may be a change of heading of at least 30 degrees, but depends of course on aircraft type), the student is to be instructed to open his eyes and return to the original flight parameters (altitude, heading and airspeed).

If this procedure fails to induce an unusual attitude (UA), or significant departure from the original flight parameters, the instructor is to fly the aircraft into a UA while the student sits free of the controls with his eyes closed. The instructor will then hand control back to the student who is to recover the aircraft to the original flight parameters.

Objective: Both the techniques to regain both proper control of the aircraft and a return to the original flight parameters are to be performed correctly. Although the precise procedures are aircraft dependent, the general principles are as follows:

- Wings level;
- Pitch level;
- Apply appropriate power setting; and
- Return to original airspeed, altitude and heading.

The unusual attitudes to be achieved may be specified in the Instrument Rating Test documents. An example for helicopters is:

- An autorotative turn at low indicated airspeed and not more than 30° angle of bank.
- A descending turn at high indicated airspeed and not more than 30° angle of bank.

4.3.5 Training the Trainers

Flight Instructors are to be taught to perform and assess these procedures during their own instructor training (see also Chapter 7).