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Handbook of Airsickness for the Canadian Forces Air Navigation School (CFANS)

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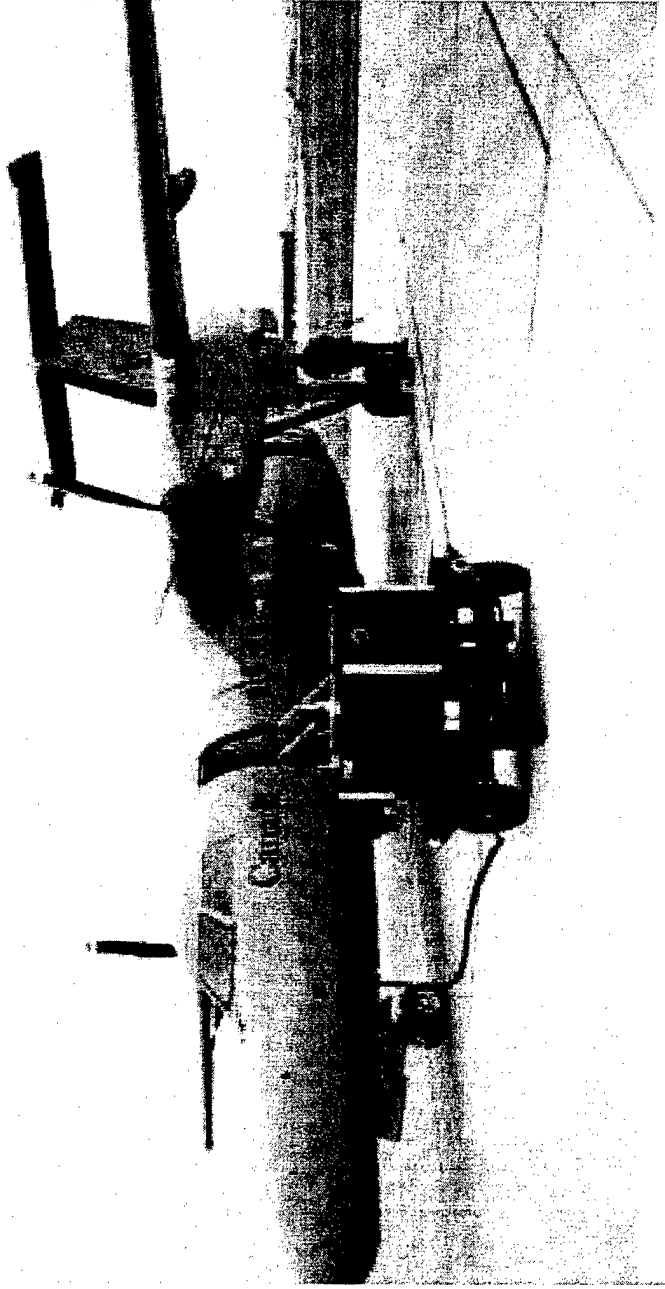
**HANDBOOK OF AIRSICKNESS
FOR THE
CANADIAN FORCES AIR NAVIGATION SCHOOL
(CFANS)**

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Executive Summary

Airsickness is a common occurrence among aircrew trainees, particularly during the initial training phase. It is well known that motion sickness afflicts the passenger far more than the driver of the vehicle. Navigators present a uniquely different problem from the pilots and other on-board aircrew. The navigator spends a great deal of time with his head down in the aircraft cabin. At low levels, he is subjected to turbulence and increased G_z^1 forces during prolonged bank-turns without the benefit of anticipating aircraft motion. For example, the navigator who is reading maps while the aircraft is manoeuvring, experiences angular motion sensed by the semicircular canals, but there is no visual evidence of rotation because the visual field of view is confined to the static environment of the workstation. Eye movements that are normally induced by the vestibular system's response to angular motion have to be suppressed if visual degradation for the task at hand is to be avoided.

Over the years, the Canadian Forces Air Navigation School has encountered cases of chronic airsickness in student-navigators. In an extreme case, the phenomenon resulted in a course removal and eventual declaration of unfit aircrew. The removal of a student from the course after delays is ineffective and also disrupts the training schedule and performance of other aircrew. Therefore, airsickness has financial implications by contributing to the failure rate in a costly training program.

The objectives of this handbook are to assist student-navigators to dispel myths about airsickness, to recognize the mechanism of airsickness during their initial training, to provide some practical countermeasures and to propose future training strategies in order to minimize the impact of airsickness on operation. Although this handbook is written specifically for CFANS and the investigation into the specific cause of airsickness in navigators is based on the CT-142, other CF navigators, aircrew and flight surgeons may find some of the information useful as well.

Key words: airsickness, vestibular, disorientation, habituation, and countermeasures.

¹ G_z forces – increased acceleration or G forces down the spine.

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Introduction

Airsickness is associated with other forms of motion sickness, such as seasickness, carsickness, simulator sickness and space sickness. While the causative physical stimuli may be very different, the effects are characterized by a similar progression of signs and symptoms from malaise², pallor³, in some individuals there is flushing as part of skin reaction (1), cold sweating to nausea and vomiting. It is a common occurrence among aircrew trainees; the problem is most acute in the early stages of training. It is interesting to note that in spite of their unusual susceptibility to various types of motion sickness, there are some famous individuals who were able to maintain superb performances in their duties. For example, Julius Caesar is reported to have suffered from motion sickness from riding chariots. Admiral Lord Nelson was a chronic sufferer of seasickness, even on his final voyage to fight at Trafalgar. Sir Charles Darwin never missed a chance to get off the boat during his famous voyage on the Beagle due to seasickness. Sir Lawrence of Arabia is reported to have suffered from motion sickness from riding camels. Nowadays, over 70% of astronauts will succumb to space sickness within the first 72 hours in orbit (2).

As mentioned briefly above, the cardinal symptom of airsickness is nausea; the cardinal signs are pallor, sweating, retching and vomiting. The particular signs and symptoms of airsickness are not significant when compared to the effects that they have on the individual's ability to concentrate and to carry out his task. Not only will it waste training time, it also makes it difficult for the instructor to assess the student's true ability. For example, if a trainee feels mildly unwell but keeps symptoms hidden, performance may be attributed to a lack of skill or potential. Therefore, airsickness has financial implications by contributing to the failure rate in a costly training program.

The incidence and severity of airsickness varies widely according to the particular circumstances. It depends on the type of student; the organization of the flying program; weather conditions; and aircraft types. It has been reported that approximately 50% of navigators of high performance aircraft suffer from airsickness and some 40% of student pilots are also affected, the sickness being of sufficient severity in 15% of these cases to interfere with training (3).

Over the years, the Canadian Forces Air Navigation School (CFANS) has encountered cases of chronic airsickness in student-navigators (4). The occurrence of airsickness during a group-training situation, as in CFANS, will delay and disrupt the training schedule and performance of other aircrew. In the

² Malaise - a feeling of general discomfort and uneasiness.

³ Pallor - turning pale in the facial area and around the mouth.

extreme, it may result in removal from the course and eventual declaration of unfit aircrew, which is highly ineffective under current fiscal restraint.

For those who are susceptible to airsickness, it is natural to feel distressed. However, all susceptible aircrew should be reassured that airsickness is a normal physiological and psychophysical response to unusual motion brought about by aircraft motion and other circumstantial factors. Individuals who lack a functional vestibular system⁴ also known as the organ of balance, are immune to motion sickness. Like their predecessors, student-navigators will overcome this malady to varying degrees as they learn to deal with the problem and to regain confidence in their ability to succeed.

A multi-faceted approach has been proposed to deal with airsickness problems with the student-navigators (5). As a first stage of the proposed program, the objective of this handbook is to raise awareness and understanding of airsickness unique to the environment for the student-navigators at CFANS. It serves to enhance the students' knowledge of airsickness in the CT-142, to dispel any myths and to lower their anxiety towards this unpleasant and debilitating phenomenon.

Signs and Symptoms⁵ of Airsickness

The cardinal **signs** of airsickness are:

1. Pallor and/or flushing in the facial area,
2. Cold sweating,
3. Vomiting or retching.

Facial pallor arises from the constriction of surface blood vessels. In some persons a greenish tinge may become apparent. Sweating often occurs even when the thermal conditions would not make this necessary. Vomiting is usually preceded by nausea but can occur sometimes without nausea (6). The physiological mechanism of vomiting and retching is identical except that vomiting involves the forced expulsion of stomach contents and psychologically it is more gratifying afterwards, as it usually provides a rapid relief from nausea. However, retching is unproductive (no expulsion of stomach contents) and usually the feelings of malaise linger for a while.

⁴ The vestibular system is an extremely sensitive sensory organ in the inner ear that provides information as to the nature of the movements of an individual and one's position in space.

⁵ Signs are objective evidence of the physical manifestation of airsickness, for example, one can observe a person turning pale in the face. Symptoms are phenomenon of sickness that leads to the complaints on the part of the individual that was afflicted, for example, subjective experience and evaluation of increased salivation or nausea.

The cardinal **symptom** of airsickness is nausea. It is thought that nausea is the conscious awareness of activity in the central mechanisms of vomiting (7). There are other signs and symptoms associated with airsickness. They commonly occur in an orderly sequence as follows: stomach awareness, stomach discomfort, pallor, cold sweating, drowsiness/yawning, feeling of bodily warmth, increased salivation, nausea and vomiting/retching. The common after-effects are headache (especially frontal), apathy, anorexia⁶, general malaise, dizziness, light-headedness or disorientation, flatulence, feeling miserable or depressed, especially with motion of long duration.

The time scale for the symptom development is determined primarily by the intensity of the stimulus and the susceptibility of the individual (8). Therefore, individuals vary in their response, certain individuals may experience many of the above effects, feeling ill for a considerable amount of time, but they may not vomit; others may have a relatively short warning period (few signs and symptoms), vomit and feel better almost immediately. The rapid relief is partially attributable to the fact that salivation, stomach disturbance, respiratory and heart rate changes are also part of the organized chain of events that comprise the act of vomiting. If exposure to the motion continues, nausea increases in intensity and results in vomiting or retching. For the more susceptible individuals, the cyclical pattern may last for several hours or days. Dehydration and disturbance of electrolyte balances in the body brought about by the repeated vomiting compounds the disability.

There are also changes in behaviour and performance (7) such as:

1. Loss of well being is at least a distraction from navigation duties.
2. Decreased spontaneity, inactivity, being quiet and subdued.
3. Decreased muscular co-ordination and eye-hand coordination.
4. Decreased ability to estimate time.
5. Decreased performance of arithmetic computation

It should be emphasized that the impact of motion sickness on performance varies independently from reported symptoms. There are many individuals who vomit that are apparently able to carry out their duties efficiently both immediately before and after the vomiting episode. Others who report nothing more than general malaise or slight nausea are apparently reduced to such a state of inefficiency over a relatively long period that the training value of their trip is largely negated.

⁶ Anorexia – absence of appetite.

Sensory Systems for Orientation and Motion

Before we discuss the causes of airsickness, a basic understanding of the sensory-motor systems involved in motion sickness is essential. These sensory-motor systems are those that are responsible for our orientation relative to the surface of the earth. Airsickness may increase the probability of failure to maintain adequate orientation awareness, a result of the distraction of coping with vomiting or the depression and malaise associated with airsickness.

In a normal terrestrial environment, our perception of position, motion and attitude with respect to the fixed frame of reference⁷ is based on the neural integration of information from three independent sensory systems. These are the somatosensory (including proprioceptive and tactile cues), vestibular (inner ear) and visual sensory systems. The proprioceptive system involves the muscle, tendon and joint sense of position while the tactile cues involve the mechanoreceptors, which respond to touch and pressure. The vestibular system is embedded in the temporal bone on each side of the skull (see Figure on page 6) and its main function is the detection of angular and linear acceleration, including tilt against gravity. To a lesser extent, the auditory system also provides information on orientation. In most vertebrates, the proprioceptive and tactile system is the first sensory system to develop, followed by the vestibular system, the auditory system and finally the visual system (9).

The Visual System

Our eyes are the most important sensory organs for spatial orientation especially in aviation. In the absence of external visual cues, the navigator can appreciate aircraft altitude and position over the earth with the aid of the radar display. In fact, individuals without a functioning vestibular system have virtually no problems of spatial orientation unless they are deprived of vision. Vision often serves to locate and detect motion of objects relative to the body. Our visual system can be divided into focal and ambient vision. Focal vision uses the central 30 degrees of the visual field. It is concerned with object recognition and identification; i.e. it answers the question of "what". Ambient vision uses the peripheral visual field. It is primarily involved with spatial localization and orientation of the individual and is concerned with the question of "where" (10). The combined action of the two is obvious, for example, we could read (occupying our central vision) and simultaneously walk (relying on our peripheral vision) in our daily lives.

⁷ The fixed frame of reference is provided by the gravitational vertical and the surface of the earth.

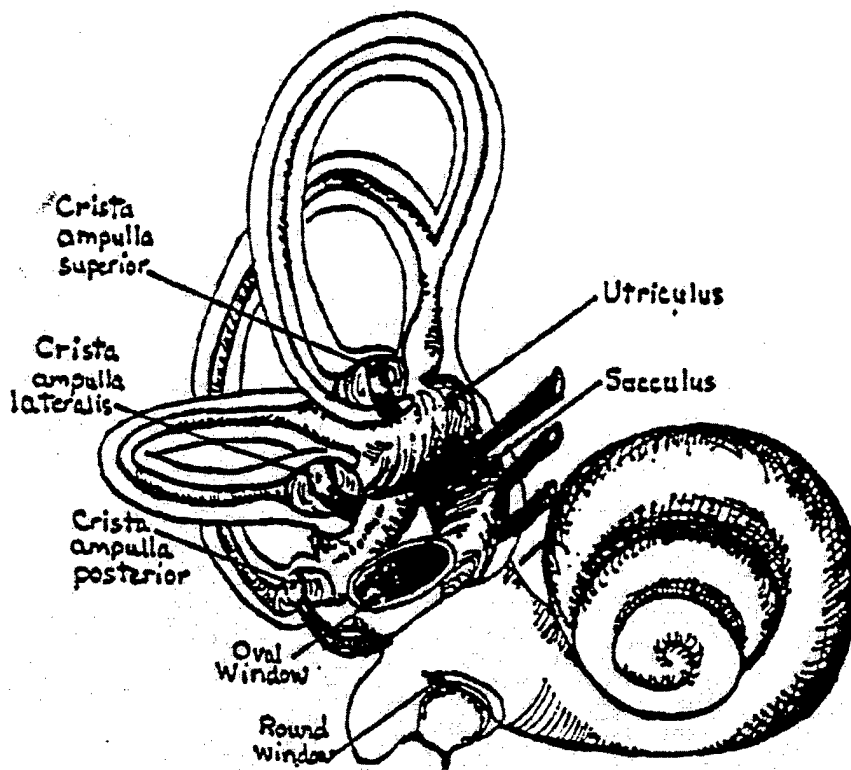
The Vestibular System

The vestibular system (organ of balance) does not have the conscious prominence of vision, audition, touch, taste and smell. Normally one is unaware of any vestibular dimensions of sensory experience, only with malfunction of the system with resulting dizziness, nausea and other symptoms does the function of the vestibular mechanism attain prominence. It serves exclusively to detect motion of the head and body relative to the earth and to generate reflexive motor activity that improves our control of motion while it is in progress. The vestibular system is housed in the inner ear embedded in the temporal bone of each side of the head.

There are two principal components: (i) three semicircular canals (superior, lateral and posterior) arranged at approximately 90 degrees to each other and (ii) the utricle and saccule, which contain the otolith organs. The semicircular canals detect angular acceleration and the otolith organs detect linear acceleration (including gravity). Since the vestibular apparatus acts as accelerometers, during prolonged constant velocity rotation or translation, our organ of balance will not be able to provide further motion signals. There is also an ambiguity in the signals of the otolith organ as it detects linear acceleration and gravity but is not able to distinguish between the two. If an aircraft were to accelerate, the otolith organ is stimulated in the same manner, as it would be by an appropriate upward pitch of the aircraft. If the aircraft is in clouds, the pilot may correct for this false sensation of upward pitch by bringing the nose of the aircraft down, he may then fly the aircraft into the ground.

A schematic illustration of relations among the semicircular canals, the utricle and the saccule is presented in the next page.

The following diagram illustrates the orientation of the vestibular system from the right ear of a subject facing out of the page. The three semicircular canals (superior, lateral and posterior) arranged at approximately 90 degrees to each other terminate at an expanded portion called crista ampulla which in turn is connected to the otolith organs (utricle and saccule).



The Somatosensory System

Although the visual and vestibular systems play a dominant role in orientation, there are other sensory receptors that can not be ignored. They are classified under the somatosensory system as the proprioceptors, including the muscle spindles responding to stretch, Golgi tendon organs responding to tension, joint receptors responding to joint motion and position. The mechanical tactile receptors of the skin respond to touch and pressure. Similar to vision, the somatosensory system serves to locate and detect motion of objects relative to the body.

In the absence of vision, our vestibular and somatosensory systems allow us to maintain spatial orientation. Similarly, in the absence of vestibular function, vision and the somatosensory systems are sufficient for orientation and balance. However, when two components of this triad are absent or compromised, it is impossible to maintain sufficient spatial orientation to maintain postural stability and effective motion.

General Causes of Airsickness

The importance of conflicting sensory cues (where sensory signals from the eyes and the vestibular system do not agree) as the principal cause factor of motion sickness was suggested more than a century ago by Irwin (11). This theory of sensory conflict has since been revised and extended. The prescribed conflict is not limited to signals from the visual system, the vestibular system and somatosensory receptors; in addition these signals are also at variance with those that the central nervous system (brain) expects to receive. Therefore, the conflict theory of motion sickness holds that in motion sickness environment, the pattern of sensory inputs concerning orientation and motion is in conflict with the pattern of inputs anticipated on the basis of past experience (8). Examples of sensory conflict are listed in the next section.

However, the theory of a simple conflict causing sickness is insufficient, as it does not explain habituation to provocative stimuli or the after-effects of exposure to such stimuli. In addition, the sensory conflict theory does not explain why such a conflict should produce vomiting. A further modification suggested that conflicting sensory inputs are interpreted centrally as neurophysiological dysfunction caused by poisoning (12) and that some evidence concerning the basic validity of this "poison" theory was provided by Money and Cheung (13) and Ossenkopp et al (14). There are other theories related to the cause of motion sickness, but they are beyond the scope of this handbook. In general, the sensory

conflict theory is satisfactory as all known causes of sickness can be accommodated by this theory and it suggests some useful preventive measures.

Examples of Sensory Conflict in Flight

Two types of sensory conflicts are possible: A. Conflict between the visual system and the vestibular system; B. Conflict between the components of the vestibular system (semicircular canals and otoliths.) Within each type, there are 3 possible combinations of such conflict. (adapted and modified from Benson 15).

A. Conflict between the visual and vestibular signals

1. The visual and vestibular system simultaneously give contradictory information or information that is not correlated. For example, when using binoculars or night vision devices (NVD) to view ground or aerial targets from a moving aircraft, these optical devices cause visual distortion of the visual field so that natural head movements result in unexpected movements of the visual scene.

2. The availability of visual information in the absence of coherent vestibular signals, for example, flying a fixed-based simulator where there are no actual movements accompanying the changing visual scene.

3. Motion signals sensed by the vestibular system in the absence of expected visual signals. For example, in a moving CT-142, the student-navigator facing the starboard side, having only the radar screen and instrument panel available, senses the aircraft's fore-aft translational motion or vertical oscillation provided by the vestibular system and to a lesser extent by their somatosensory system. However, the confirmation of such movement is not possible, as there are no external visual references available. Reading or charting a navigational map in the moving aircraft may also be nausea inducing for the same reason.

B. Conflict between the semicircular canal and otolith signals

1. Both the semicircular canals and otoliths give contradictory information or information that is not correlated. For example, while the aircraft is in a sharp right turn, the aircrew makes head movements in a different direction than the direction of the turn. This has been termed Coriolis cross-coupling⁸.

2. Information from the semicircular canals in the absence of expected otolith signals. For example, after consumption of alcohol, a difference in the specific gravity of the endolymph (inner ear fluid) and the cupula⁹ results in the cupula being deflected by gravity, hence creating a sensation of rotation. However, the otolith and somatosensory system indicate that no motion has occurred.

3. Information from the otolith in the absence of expected semicircular canal signals. For examples, low frequency (< 0.5Hz) vertical oscillation induced by turbulence experienced during low level flying in the CT-142.

Specific Causes of airsickness in the CT-142 (Dash 8 Navigation Training Aircraft)

Based on the above explanation of the general causes of airsickness, there are 5 major factors that can elicit signs and symptoms of airsickness that are specific to navigators in the CT-142. Each of these factors can act separately or in combinations.

⁸ The terms "Coriolis effect" and "cross-coupling effects" are both used in referring to the vestibular effect of tilting the head during whole-body rotation. Coriolis effect can occur in flight when an individual rotates his head about one axis, the ω_2 axis, while the aircraft is rotating about another axis, the ω_1 axis. This produces an instantaneous stimulus to the semicircular canals, about a third axis, that can be both disorienting and disturbing. For example, while an aircraft is in a sharp right turn, if the head and body are rolled to the right relative to the aircraft, a false sensation of climb rate may be produced by the cross-coupled stimulus to the semicircular canals. The stimulus can be calculated from vector algebra as the vector cross-product, or cross-coupling, of the ω_1 and ω_2 velocity vectors; hence, the popularity of the term "cross-coupled effect".

⁹ Cupula is a gelatinous mass in the expanded portion of the semicircular canals where hair-like projections from the sensory cells are embedded. When the cupula is deflected by the flow of the endolymph during rotation, a sensory signal of turning is then registered by the vestibular system.

1. Turbulence during low-level flying:

Operational duties may require prolonged flight at low altitude in turbulent air while manoeuvring. It is typically of low-frequency vertical oscillation estimated to be 0.1-0.5 Hz. These low-frequency translational oscillations might alter with various distances away from the centre of gravity of the aircraft. In addition, roll motion about the longitudinal axis of the aircraft could exacerbate the discomfort.

2. Discordant¹⁰ information between cognitive command output and vestibular feedback

The navigator's workstation faces the starboard side without an external visual reference, in other words, no useful peripheral orientation cues are available. A right banking command to the pilot will result in an unexpected and unusual pitch-forward sensation with reference to the navigator; sometimes it is accompanied by an increased acceleration of up to +1.5Gz during banked turns. Similarly, a command of left bank will result in an unexpected pitch-backward sensation. In addition, cognitively, we normally associate banking (roll rotation of the aircraft) with rotation about the frontal plane (x-axis). The navigators in fact experience rotation in the sagittal plane (y-axis) in the CT-142 every time that it banks. Therefore the direct input or warnings about the flight path and intensity of attitude and direction changes are often contradictory and confusing with respect to their past experience.

3. Coriolis cross-coupling effect

During banking, head movements result in simultaneous stimulation of the semicircular canals in more than one plane, which is known to be disorienting and nauseogenic.

4. Visual and vestibular conflict

During operations, the visual field of the navigator is confined within the cabin of the aircraft. The workstation provides an apparent stationary visual frame that conflicts with varying vestibular cues during flight.

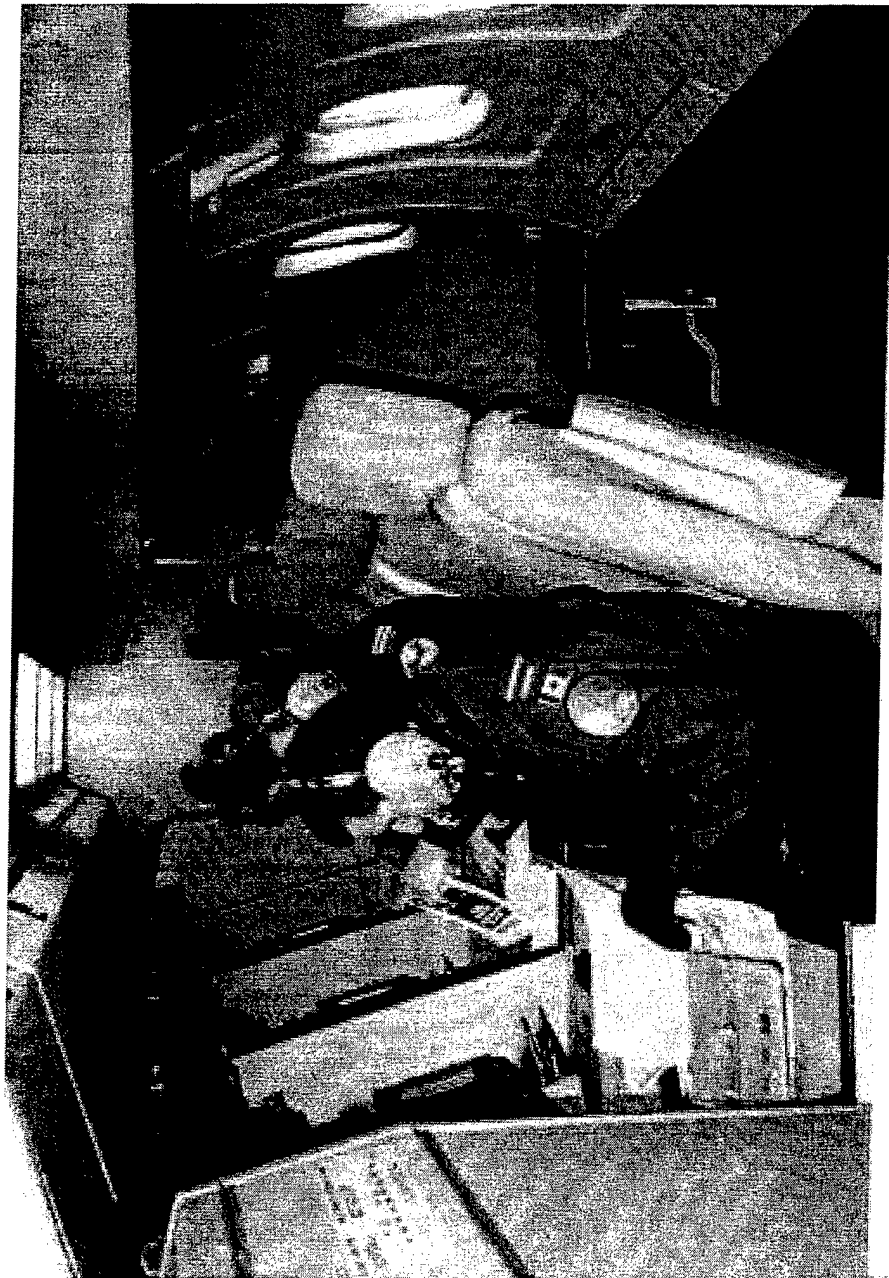
5. Visual disturbance

During their tasks (for example, tracking of the radar screen), navigators allow their eyes to follow relative movements of nearby targets. This could cause

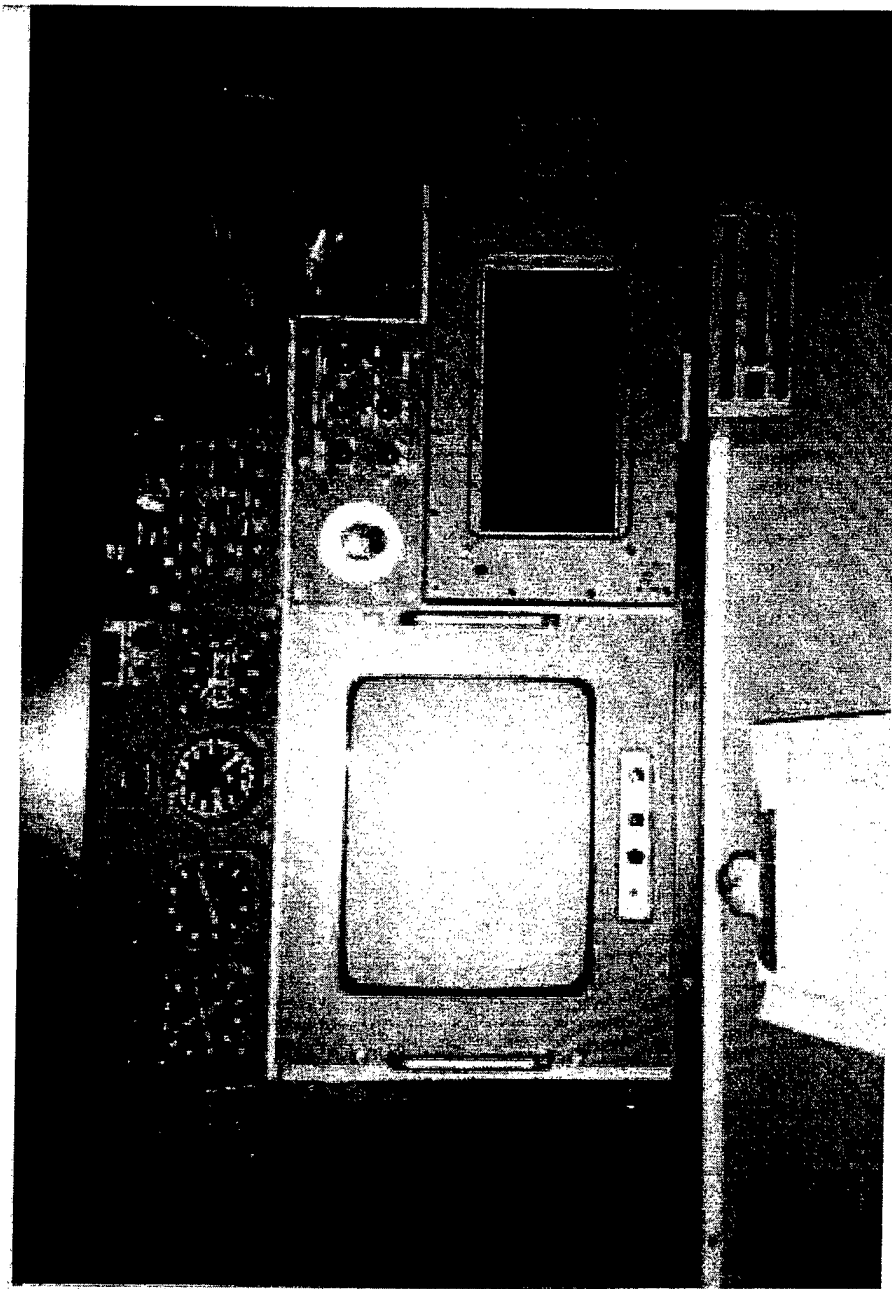
¹⁰ Discordant information – information that are not in harmony or agreement but not necessary conflicting (which suggests collision of opposed principles.)

a discrepancy between the relative movements of the target on the radar screen and the movements of the body caused by turbulence and motion of the aircraft. In reading and charting navigation maps, low-frequency movements of the map promote pursuit (following) eye movements that can be compulsive.

The cabin of the CT-142 and the workstation for the student-navigator are shown in the following figures respectively.



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Predictability of Motion Sickness in the Selection of Aircrew

The history of motion sickness has been found to be of value in predicting sickness during flight training and in predicting successful completion of flight training. There is a positive correlation between the incidence and severity of airsickness during training and the history of motion sickness prior to entry into the Royal Air Force (3). A person who has suffered from motion sickness in automobile or on buses, trains, ships, aircraft and carnival rides is much more likely to become sick in another motion environment than is a person with no history of motion sickness. Unfortunately, a comparison of information on previous history of motion sickness given at the time of selection with that obtained by a subsequent confidential questionnaire showed a large discrepancy. This finding is perhaps not surprising, since these individuals were applying for a career in aviation and no doubt felt that they would not be accepted if they admitted to a history of motion sickness. Therefore, the reliability of the history of the motion sickness questionnaire as a predictor for future motion sickness has been drawn into question.

Prevention and Management of Airsickness

Prevention of airsickness can take several forms: elimination or reduction of the cause; isolation of the body from the cause; or minimization of the effects of the cause. The cause is the motion environment, the voluntary and involuntary movements of the body (especially the head). In the operational military environment, elimination of the cause is impossible, unless the affected individual withdraws from service. However, navigators can organize their activity so that unnecessary head/body movements are restricted.

It appears that the most suitable and effective therapy for airsickness under the military operational environment appears to be habituation to the nauseogenic stimuli. Individuals who are subjected to a motion stimulus that provokes nausea and vomiting tend, with repeated exposure, to become increasingly resistant to its nauseogenic effect. This habituating response is seen in a variety of situations such as on-board ship, space flight, and in a number of laboratory stimuli. Habituation to Coriolis stimulation has been shown to demonstrate a gradual decline in intensity and an increase in tolerance to the nauseogenic effects of the cross-coupled stimuli. It is interesting to note that the suggestion of using vestibular exercises (achieved through gymnastics) to reduce susceptibility to airsickness has been proposed since 1943 by Popov (16).

The term habituation used here is distinct from adaptation. Habituation refers to the effects of repeated exposure to the stimulus, in this case, angular or linear acceleration. Furthermore, habituation is used to describe the situation where a change in susceptibility to airsickness involves conscious mental activity (such as learning the characteristics of the motion environment so as to predict future movements). Habituation may occur to a specific combination of motion cues and not all provocative stimuli.

Adaptation refers to the effects, which occur in a prolonged single exposure. It is usually reserved for situations where continuous exposure to a stimulus brings about reduced sensitivity through a change in the relevant sensory organs. Such adaptation has not been shown to occur with motions causing motion sickness and would not explain adequately the manner in which motion sickness susceptibility varies with exposure to provocative motions.

However, the phenomenon of habituation or possible adaptation to motion sickness invokes other questions that have not been resolved. This is partially due to the fact that the acquisition of habituation, similar to motion sickness susceptibility, shows individual variation. What factors determine the rate of habituation? To what extent can habituation gained from one environment apply to another? Is there long term adaptation? What are the neurophysiological mechanisms that underlie such adaptive responses?

Desensitization Training

Desensitization on the ground has been shown to be helpful for those who do not develop sufficient protective habituation during the course of normal in-flight training by various investigators (3, 17, 18, 19, 20, 21, 22). The desensitization that results from repeated exposure to a provocative stimulus tends to be fairly specific to that type of stimulus. The basic principle is that there should be a gradual and incremental exposure to the provocative stimulus. Typical desensitization therapy for pilots involves a 2-3 week period of twice daily exposures to Coriolis cross-coupled stimuli of progressively increasing intensity. This is followed by 10-15 hours of dual flying in which the process of incremental adaptation to the more complex provocative motion stimuli of flight is carried out (3).

As mentioned earlier, motion stimuli tend to provoke sickness when the motion elicits patterns of sensory stimulation that do not conform to those expected on the basis of past experience. Therefore exposure to the nauseogenic manoeuvre is essential. In-flight training also provides the aircrew with the opportunity to improve their ability to predict the spatial sensory patterns that

are generated by the spatial consequence of their actions. For example, a right-banking command to the pilot would result in a pitch-forward sensation with respect to the student-navigator and vice-versa. This ability is crucial to resolve the sensory conflicts or neural mismatch under altered gravito-inertial environment and thus less able to provoke airsickness. Although there has been no in-flight experiment to determine the degree of improvement in tolerance to aircraft manoeuvres that results from tolerance gained either from cross-coupled stimuli or other ground-based training, in-flight desensitization is likely to be an important element to complement any ground-based training. This is exemplified by the fact that there are inevitably aspects of aircraft motion that cannot readily be reproduced on the ground and that subjects need to acquire the confidence that they are resistant to sickness in the air, rather than in a set of laboratory devices. It has been reported that pilots do not find themselves to be totally immune to airsickness at the start of their flying phases and that it is necessary to build up tolerance gradually (22).

Biofeedback Training and Relaxation Therapy

When operant conditioning¹¹ is used to train human subjects to control autonomic responses, the process is called biofeedback. It usually involves a variety of relaxation techniques (Jacobsonian contraction and slow relaxation, diaphragmatic breathing and relaxing mental imagery). It also involves biofeedback instrumentation recording skin surface temperature and skin conductance. These recordings are made while the subject was experiencing incremental increases in Coriolis vestibular simulation.

Physiological measures such as heart rate, blood pressure, body temperature, and galvanic skin resistance are commonly chosen as control parameters in "biofeedback" training. However, it is not clear whether a consistent and reliable relationship exists between motion sickness and these measures (7, 8, 23, 24, 25, 26, 27, 28, 29). Moreover, individuals vary greatly in the extent to which they can benefit from biofeedback training. Training conducted in the laboratory situation may not transfer to operationally relevant situations, which involves active integration with other tasks (30, 31, 32, 33, 34). It appears that biofeedback and other behavioural techniques can modify the physiological

¹¹ Operant conditioning – is one of the classical psychological behaviour conditioning exercises when a subject's response to a stimulus is reinforced. For example, a hungry rat is placed in a dimly lit box that has a movable lever connected to an electric switch. When the rat by chance presses the switch, a pellet of food is made available to the rat. The hungry rat eats and soon presses the lever again.

responses of some individuals and ameliorate the anxiety that accompanies certain noxious situations, but it remains to be seen whether these responses bear a direct relationship to the symptoms of airsickness.

Drug Treatment

It has been demonstrated in the laboratory that certain drugs can reduce the incidence and severity of motion sickness. Unfortunately none can completely prevent motion sickness in the population at risk under all conditions of provocative stimulation. In addition none of the drugs of proven efficacy in the treatment of motion sickness are entirely specific and all have side effects, which severely limit their utility. The three relatively effective and commonly used drugs (promethazine, dimenhydrinate, and scopolamine) are central depressants that can affect brain activities and cause drowsiness or sleepiness and dizziness. They should not be taken by aircrew especially those in whom an impairment of skilled performance could jeopardize safety. There is a place, however, for the administration of anti-motion sickness drugs to student-navigator or student-pilots during the early stages of training. The possible performance decrement due to sickness must be weighed against side effects that may be produced by the drugs. Those given drugs must be warned that the drugs may impair their ability to drive or operate machinery and that they should refrain from the consumption of alcohol as it will increase the sedating effect.

The choice of anti-motion sickness drugs depends on the expected duration of exposure to provocative motion and also depends upon individual differences in the incidence of side effects and its effectiveness. The rate of absorption and the duration of action of various drugs, which are of proven value in the treatment of motion sickness, vary considerably. The most common ones that are in use:

(i) Scopolamine hydrobromide (oral dose 0.3 to 0.6 mg) acts within 0.5 to 1 hour and provides protection for about 3-4 hours. It is usually taken in combination of 5 mg of dexedrine to counteract the side effect of sleepiness and drowsiness. The scopolamine is also available in a skin patch, the transdermal therapeutic system (TTS), which is applied 18 hours before the exposure to nauseogenic stimuli and the effect lasts for about 48-72 hours. The TTS system provides a loading dose of 200 μ g and a controlled release at 10 μ g per hour. Side effects include drowsiness and dry mouth, and users should wash their hands thoroughly after application of the patch as the residues from the patch can cause blurry vision. Accumulation of scopolamine has also been shown to cause short-term memory loss.

(ii) Promethazine hydrochloride (oral dose 25 mg) takes 1-2 hours to act and is effective for 8-12 hours. It is usually taken together with ephedrine (oral dose 25 mg) to counteract the side effects of sleepiness and drowsiness.

(iii) Dimenhydrinate (oral dose 50 mg) and cyclizine hydrochloride (oral dose 50 mg) are absorbed at the same rate of promethazine but their duration of action is shorter, about 6 hours.

It should be noted that once vomiting has been elicited, alternative routes of administration (for example, intramuscular¹² or intravenous injection) must be employed. Self-medication is dangerous, and it should be avoided. It is important to consult a Flight Surgeon or motion sickness expert before taking any anti-motion sickness drugs. For other effective oral regimens for the prevention of motion sickness, the readers should consult Canada Communicable Disease Report on motion sickness (35).

Unconventional Treatments

There are many unproven treatments offered for motion sickness. A variety of herbal (ginger-root), homeopathic (Cocculus, Nux Vomica, Petroleum, Tabacum, Kreosotum, Borax and Rhus Tox) remedies have been proposed. These remedies have not been found consistently effective and the various purported evidence is confusing at best. Various forms of acupuncture¹³ therapy are available as alternative treatment for motion sickness as well. Commercial devices such as wristbands, sea bands and other forms of acupressure therapy have been investigated under controlled scientific studies (36, 37) and found to be ineffective in reducing nausea and vomiting as induced by motion in humans. It is possible for the alternative remedies to appear beneficial by a combination of the placebo¹⁴ effect and habituation to the environment. Therefore, it is prudent to avoid any purported effective commercial devices until scientific validation is available.

¹² Intramuscular – within the substance of a muscle, intravenous is within the veins.

¹³ Acupuncture – puncture of the tissue with long needle or applying pressure on the body surface, for relief of pain and discomfort.

¹⁴ Placebo – An indifferent substance in the form of medicine, given for the suggestive effect or pleasing the patient.

Some Practical Recommendations to Minimize the Occurrence and/or Delaying the Onset of Air Sickness in CFANS.

Behavioural Measures

1. Be well informed about the causes of airsickness in the CT-142 (have a thorough understanding of what is presented in this handbook).
2. Do not dwell on past experience of motion sickness or worry about the occurrence of airsickness because anxiety will only inhibit habituation to the provocative environment.
3. An individual should not fly unless he feels fit and well. Do not go flying when you are hung over or have an upset stomach. Recent illness and fatigue all cause debility and adversely affect an individual's general ability in the air. They also make one prone to air sickness especially during turbulence.
4. Trainees should discuss their airsickness, as early as possible, fully and frankly with the flying instructor. Early discussion will facilitate recovery and prevent misunderstanding when the effects of airsickness decrease an individual's performance. The flying instructor could make minor adjustments to the training program, when possible, to assist the individual to habituate quickly. The trainee should be given every opportunity to be in the air whenever there is an empty seat.
5. Aircrew are likely to develop some degree of anxiety about their sickness problem. Minimizing the anxiety by introducing the trainee gradually to the type of motion that might be experienced using ground-based devices will be useful.
6. It is useful to be familiar with one's symptom development of motion sickness on the ground, beginning with mild Coriolis stimulation and progressively to more provocative and specific stimulus.
7. It is useful to be involved and to concentrate on the task at hand which minimizes introspection and attention to bodily function. This is evident by the fact that the person least likely to be airsick is the pilot of the aircraft or driver of the car. However, when it is not possible to be in control of the aircraft, involvement in some absorbing task is better than being preoccupied with the state of one's stomach.
8. Minimize unnecessary motion of the head when possible. This can be facilitated by head support, body restraint and good organization before the navigational tasks begin. Keep to a minimum the number and magnitude of head

movements especially large nodding movements during turbulence or during changes of aircraft heading and airspeed when possible.

9. Do not self-medicate with over-the-counter anti-motion sickness drugs. In certain selected aircrew, a flight surgeon may decide to prescribe some form of medication. Be aware that all the current effective anti-motion sickness drugs have side effects. These side effects include dryness of the mouth, sleepiness, and dizziness. In some cases serious visual disturbance includes double vision.

10. Food Consumption

The fear of airsickness sometimes results in avoidance of food intake, but experimental studies have found no evidence that the time of day of motion exposure or its relation to meal times has any effect on the incidence of motion sickness (38, 39). Excessive consumption of food may be best avoided since it may increase the volume of vomitus, and therefore, both the fear of sickness and the extent of any subsequent inconvenience. It is generally agreed that vomiting is less unpleasant when the stomach contains something to vomit than an empty stomach. It is recommended that aircrew should maintain a normal light consumption of food and drink.

11. Avoidance of Alcohol

Recent changes to flying orders have standardized the policy regarding alcohol consumption. Crew members shall not consume alcohol for at least 12 hours prior to flying and in no case less than eight hours prior to reporting for duty. It is well known that the after-effects of alcohol (hangover) adversely affect an individual's general ability. As discussed previously, alcohol could cause semicircular canal conflict. It has also been shown that alcohol affects the visual feedback of target position during voluntary and involuntary head movement (40). After the blood alcohol concentration has been raised high enough¹⁵ and the alcohol has subsequently disappeared from the blood it continues to have measurable effects (41, 42) on the brain, on the vestibular system, and in some cases on blood sugar. Motion sick aircrew have observed that their susceptibility to air sickness is increased by even moderate amounts of alcohol in the previous 24 hours (43), and this effect of alcohol has also been observed on tolerance to cross-coupled stimulation during desensitization treatment (21). Of course, excessive consumption of alcohol can result in vomiting without provocative motion.

¹⁵ Depending on the individual and the speed of ingestion, in most cases four to six drinks, would be sufficient to raise the blood alcohol concentration over 100mg% which is certainly high enough.

The eight-hour rule is quite inadequate for heavy drinking¹⁶, since there would still be significant concentrations of alcohol in the blood eight hours after a peak blood alcohol concentration of 150mg%. Under some circumstances, there are measurable decrements of pilot performance even at 14 hours after a peak blood alcohol concentration of only 100mg%. The current recommendation for commercial airline pilots is 24 hours after a blood alcohol concentration of 150mg% before flying. For those taking anti-motion sickness medications, it is important to note the increased sedation from alcohol.

Environmental Considerations

1. When possible, locate the most susceptible student-navigator initially at positions where low frequency vertical oscillation is least, i.e. towards centre of the aircraft
2. Provide optimal environmental conditions, suitable temperature and ventilation when possible.

¹⁶ Heavy drinking is defined as having a blood alcohol concentration of 150mg% among occasional drinkers in a social setting.

Conclusion

Airsickness has significant economic consequences when it contributes to the failure rate in an expensive training program. Some form of treatment program for airsickness is necessary. Currently a practical selection test to eliminate candidates that are prone to airsickness before and during the introductory sortie of the training is not available. Drug treatment of airsickness in the military has to balance the loss of operational effectiveness produced by airsickness with the possible detrimental effect on performance from the side effects of the drugs. Various schemes involve habituation to ground based motion stimuli that are nauseogenic have been described by various investigators. Some use biofeedback and relaxation techniques in addition to habituation. These programs vary in the extent to which remedial flying is incorporated into the program. Detailed comparison of results is complicated by differing criteria of success, however it is possible to reduce the number of trainees who would otherwise be eliminated from training on account of persistent sickness.

In conclusion, airsickness is a normal physiological response to an unusual force environment, although it is common in the early stages of training, the majority of aircrew students will overcome it quite quickly with flying practice. This also applies to individuals who are returning to flying after a period of duty on the ground.

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Airsickness is a common occurrence among aircrew trainees, particularly during the initial training phase. It is well known that motion sickness afflicts the passenger far more than the driver of the vehicle. Navigators present a uniquely different problem from the pilots and other on-board aircrew. The navigator spends a great deal of time with his head down in the aircraft cabin and at low levels he is subjected to turbulence, increased Gz during prolonged bank-turns without the benefit of anticipating aircraft motion. For example, the navigator who is reading maps while the aircraft is manoeuvring experiences angular motion sensed by the semicircular canals, but because the visual field of view is confined to objects within their immediate work station. The lack of visual evidence of rotation and any vestibular-induced eye movements has to be suppressed if visual degradation for the task at hand is to be avoided.

Over the years, the Canadian Forces Air Navigation School has encountered cases of chronic airsickness in student-navigators. In an extreme case, the phenomenon resulted in a course removal and eventual declaration of unfit aircrew. The removal of a student from the course after delays is ineffective and also disrupts the training schedule and performance of other aircrew. Therefore, airsickness has financial implications by contributing to the failure rate in a costly training program.

The objectives of this handbook are to assist student-navigators to dispel myths about airsickness, to recognize the mechanism of airsickness during their initial training, to provide some practical countermeasures and to propose future training strategies in order to minimize the impact of airsickness on operation. Although this handbook is written specifically for CFANS and the investigation into the specific cause of airsickness in navigators is based on the CT-142, other CF navigators, aircrew and flight surgeons may find some of the information useful as well.

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airsickness, vestibular, disorientation, habituation, and countermeasures.