


**16.687**  
**Private Pilot Ground School**  
**Massachusetts Institute of Technology**  
**IAP 2019**

Human Factors

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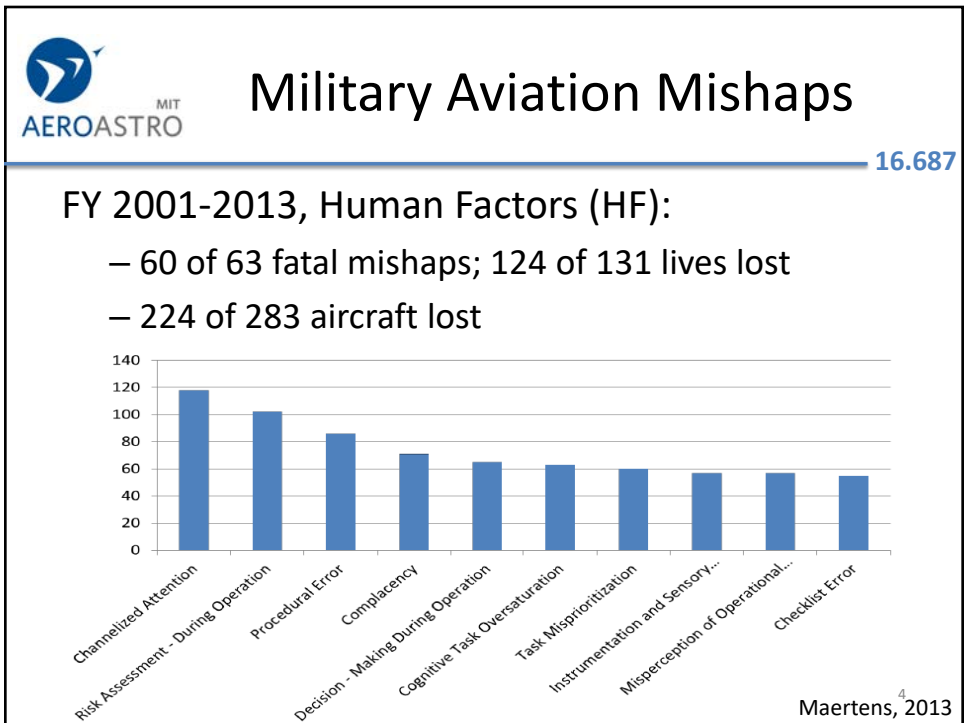
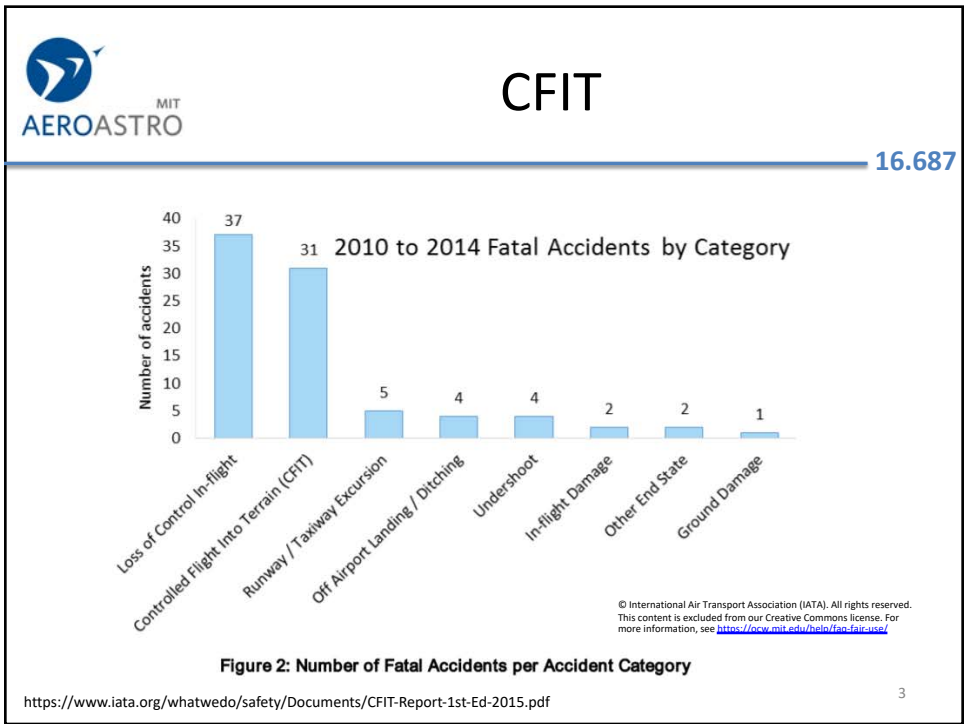
**To Learn More...**

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- 16.400
- <https://www.nts.gov/investigations/Accident Reports/Reports/AAR0001.pdf>

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## “It is the pilot’s fault”

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- A new \$800,000 four-seat airplane or \$5 million turboprop won't have 1/100<sup>th</sup> of the intelligence of a \$500 DJI drone
- A \$27 million certified-in-2018 business jet has nearly every knob, button, and dial as a 1944 B-29. Why not one button “configure yourself for takeoff?”
- There is no such thing as regulatory error.
- There is no such thing as engineering error.
- Thus we are left with “pilot error.”

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## Practice Question

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A lack of orientation with regard to the position, attitude, or movement of the aircraft in space is defined as

- A. Pilot Error
- B. Oxygen narcosis
- C. Spatial disorientation
- D. Situation awareness

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## Practice Question

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A lack of orientation with regard to the position, attitude, or movement of the aircraft in space is defined as

- A. Pilot Error
- B. Oxygen narcosis
- C. Spatial disorientation**
- D. Situation awareness

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## Outline

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- Aeromedical Factors
- Aeronautical Decision-Making

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## Private Pilot Ground School

# Aeromedical Factors



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## Medical Certificate

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- Private pilots must obtain a medical certificate to exercise privileges
- Aviation Medical Examiners (AME) issue medicals; these are typically doctors who fly
- Three classes of medical certificates (FAR 61.23)
  - Private or CFI: Third class valid for 60 months (5 years) if under 40
  - Commercial flying: Second class, valid for 12 months
  - Airline flying: First class, valid for 12 months if under 40
- Since 2017: fly with up to six people (under 6,000 lbs.) under BasicMed.

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## Aeromedical Factors

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- Health and Physiological factors affecting pilot performance
  - Hypoxia & Hyperventilation
  - Middle ear and sinus problems
  - Spatial Disorientation and Illusions
  - Vision

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## Hypoxia: Reduced Oxygen

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- insufficient oxygen to the brain
- Types
  - Hypoxic hypoxia: insufficient oxygen available
    - Reduction in partial pressure of oxygen at high altitude
  - Hypemic hypoxia: blood can't transport oxygen to the cells
    - CO poisoning
  - Stagnant hypoxia: oxygen-rich blood not moving to tissue
    - Excessive acceleration of gravity (Gs)
  - Histotoxic hypoxia: cells can't effectively use oxygen
    - Alcohol and drugs
    - 1 ounce of alcohol  $\approx$  2,000 feet physiological altitude

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## Hypoxia Symptoms

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- Impaired judgment
- Visual impairment
- Decreased reaction time
- Euphoria
- Drowsiness
- Lightheaded or dizzy sensation
- Headache
- Cyanosis (blue fingernails and lips)
- Tingling in fingers and toes
- Numbness



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If the pulse oximeter shows less than 90, you're reading your IQ.

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## Hypoxia

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## Carbon Monoxide (CO) Poisoning

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- Tesla heats the cabin with a wire
- Toyota Camry heats the cabin with a hot water pipe
- Cessna 172 heats the cabin by running air over the exhaust pipe

What could go wrong? Exhaust pipes corrode and crack.

Symptoms (form of hypoxia):

- Headache
- Blurred Vision
- Dizziness
- Drowsiness
- Loss of muscle power

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## Preventing CO Poisoning

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- CO is a colorless and odorless gas produced by all internal combustion engines
- There are detectors: simple stick-on and built-in electric ones (standard on Robinson R44)
- Careful inspections by mechanics
- Replace components periodically



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(Not an issue in the turbine world; heat comes from fresh compressed “bleed air.”)

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## CO Poisoning Continued

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### Symptoms reminder:

- Headache
- Blurred Vision
- Dizziness
- Drowsiness
- Loss of muscle power

### Smell exhaust or experience symptoms?

- Turn off any heater
- open fresh air vents and windows
- use supplemental oxygen

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## Hypoxia Recap

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- insufficient oxygen to the brain
- Types
  - Hypoxic hypoxia: insufficient oxygen available
    - Reduction in partial pressure of oxygen at high altitude
  - Hypemic hypoxia: blood can't transport oxygen to the cells
    - CO poisoning
  - Stagnant hypoxia: oxygen-rich blood not moving to tissue
    - Excessive acceleration of gravity (Gs)
  - Histotoxic hypoxia: cells can't effectively use oxygen
    - Alcohol and drugs
    - 1 ounce of alcohol  $\approx$  2,000 feet physiological altitude


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## G-Induced Loss of Consciousness (G-LOC)

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## Hyperventilation

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- Excessive rate and depth of respiration leading to abnormal loss of carbon dioxide from the blood
- Symptoms:
  - Visual impairment, Unconsciousness, Lightheaded or dizzy sensation, Tingling sensations, Hot and cold sensations, Muscle spasms
- Pilots encountering an unexpected stressful situation may subconsciously increase their breathing rate
  - If flying at higher altitudes, a pilot may have a tendency to breathe more rapidly than normal, which often leads to hyperventilation
- To recover → breath normally (slow breathing rate), breath into a paper bag, talk aloud

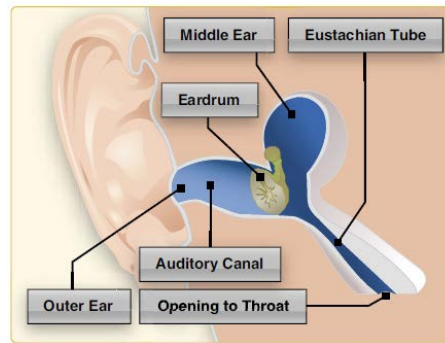
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## Middle Ear and Sinus Problems

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- climbs and descents → pressure inside of body must equalize
  - If gas escape is impeded, painful pressure builds
  - If the pilot has a cold, ear infection, or sore throat, it may not be possible to equalize the pressure



Source: Public Domain

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## Spatial Disorientation and Illusions

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- Lack of orientation with regard to the position, attitude, or movement of the airplane in space
- Your body uses three systems working together to ascertain orientation and movement in space
  - Visual system
  - Vestibular system: organs in the inner ear used to determine balance
  - Somatosensory system: nerves in the skin, muscles, and joints which sense position based on gravity and feeling → “seat of the pants”

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## Spatial Disorientation

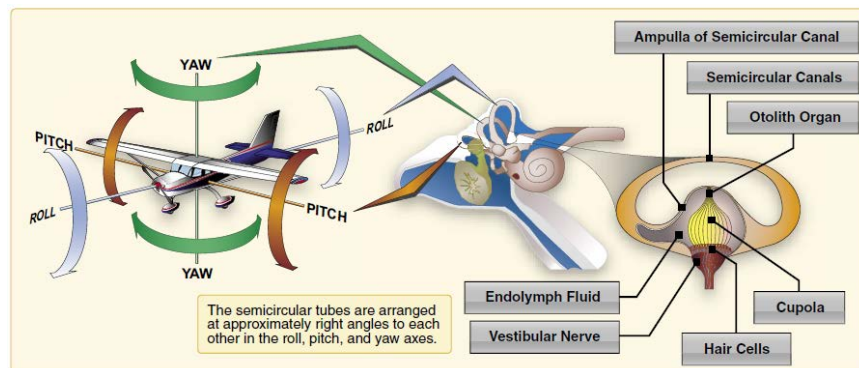
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- When flying in VMC, your eyes are your major orientation source
- When flying in IMC, the visual cues are removed and false sensations can cause disorientation
  - The body can't distinguish between acceleration forces due to gravity and those resulting from maneuvering the aircraft

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## Vestibular System

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Source: Public Domain

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## Spatial Disorientation

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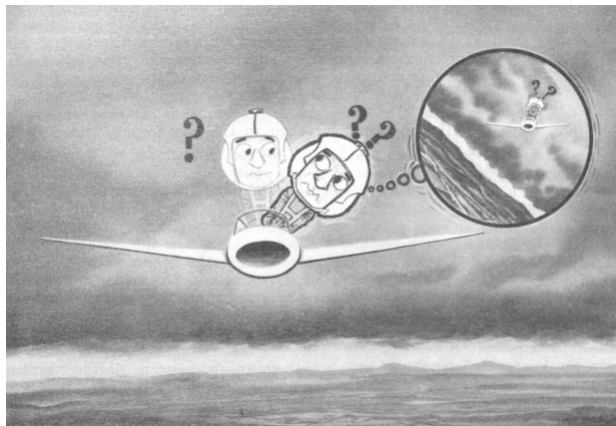
- Solution:
  - Prevention → flight should be avoided in reduced visibility or at night when the horizon is not visible
  - Training → Instrument rating
  - Awareness → Understand the types of illusions



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## Vestibular Illusions – The Leans

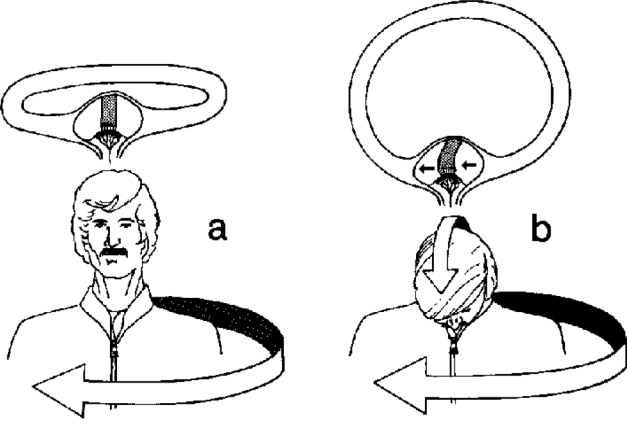
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 **Vestibular Illusions – Coriolis Illusion** 16.687

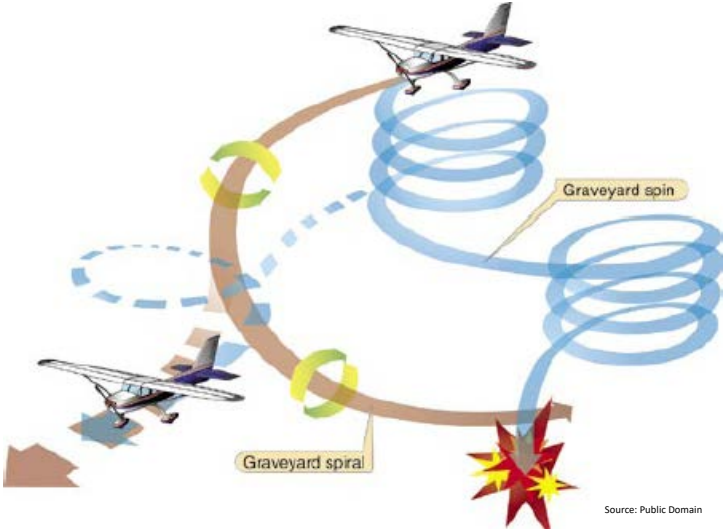


The diagram illustrates the Coriolis illusion in two parts, labeled 'a' and 'b'. Part 'a' shows a person's head with a horizontal ring above it, and a curved arrow below the neck pointing to the left, indicating rotation. Part 'b' shows a similar setup but with a vertical ring above the head and a curved arrow below the neck pointing to the left. The vertical ring is tilted, and a horizontal arrow points from the center of the ring towards the right, representing the Coriolis effect.

Source: Public Domain

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 **Vestibular Illusions – Graveyard Spiral** 16.687



The diagram illustrates the Graveyard Spiral illusion. It shows a brown path that curves to the right. A blue spiral line follows the path, representing the aircraft's path. Two airplanes are shown: one at the start of the curve and one at the end of the curve. A red starburst symbol is at the end of the path. Labels 'Graveyard spiral' and 'Graveyard spin' are present. The 'Graveyard spiral' label points to the blue spiral line, and the 'Graveyard spin' label points to a yellow circular arrow on the path.

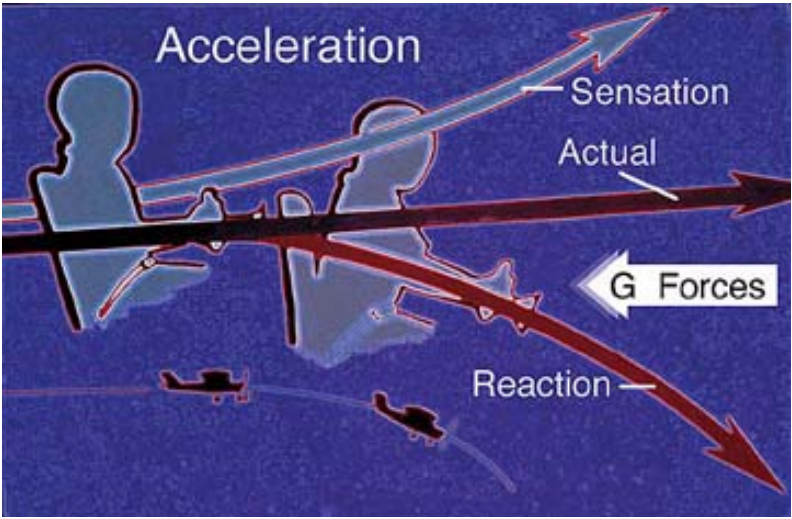
Source: Public Domain

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## Vestibular Illusions – Somatogravic Illusion


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The diagram illustrates the Somatogravic Illusion. It shows a silhouette of a pilot in a cockpit. A blue arrow labeled 'Acceleration' points upwards and to the right. A red arrow labeled 'Sensation' points upwards and to the right, indicating the pilot's perceived direction. A black arrow labeled 'Actual' points horizontally to the right. A white box labeled 'G Forces' with a black arrow points to the left, representing the inertial force. A red arrow labeled 'Reaction' points downwards and to the right, showing the pilot's control input. Below the pilot, a small airplane is shown in a climb, with a blue arrow indicating its actual path.

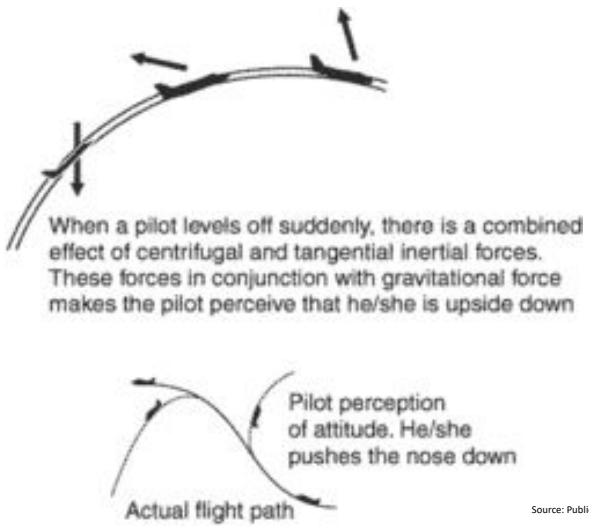
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Source: Public Domain



## Vestibular Illusions – Inversion Illusion

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The diagram illustrates the Inversion Illusion. It shows a curved flight path with arrows indicating direction. Below the path, text explains: "When a pilot levels off suddenly, there is a combined effect of centrifugal and tangential inertial forces. These forces in conjunction with gravitational force makes the pilot perceive that he/she is upside down". Below this, another diagram shows a curved path labeled "Actual flight path" and a text box stating: "Pilot perception of attitude. He/she pushes the nose down".

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Source: Public Domain



## Spatial Disorientation and Illusions

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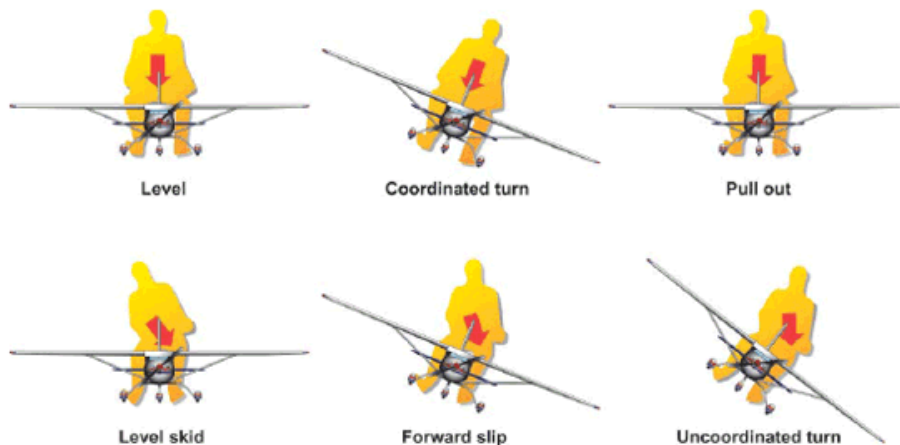
- Lack of orientation with regard to the position, attitude, or movement of the airplane in space
- Your body uses three systems working together to ascertain orientation and movement in space
  - Visual system
  - Vestibular system: organs in the inner ear used to determine balance
  - Somatosensory system: nerves in the skin, muscles, and joints which sense position based on gravity and feeling → “seat of the pants”

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## Postural Considerations

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Skid, slip, and uncoordinated turns feel alike.  
Pilots feel they are being forced sideways in their seat.

Source: Public Domain

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## Demonstration of Spatial Disorientation

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- Controlled aircraft maneuvers to experiment with spatial disorientation
  - Climbing while accelerating
  - Climbing while turning
  - Diving while turning
  - Tilting to Right or Left
  - Reversal of Motion
  - Diving or Rolling Beyond the Vertical Plane

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## Coping with Spatial Disorientation

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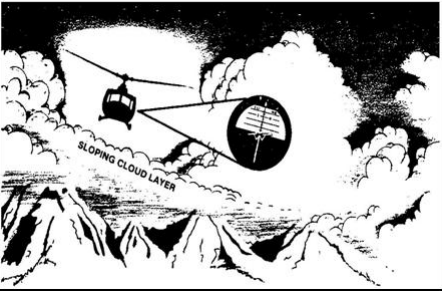
- Understand the causes of illusions and remain alert for them
- Obtain a preflight weather briefing
- Obtain training and maintain proficiency before flying in marginal visibility
- Do not continue flight into adverse weather conditions unless proficient
- Avoid sudden head movements
- Be physically ready to fly: rest, diet, night adaptation
- Become proficient and rely on your flight instruments

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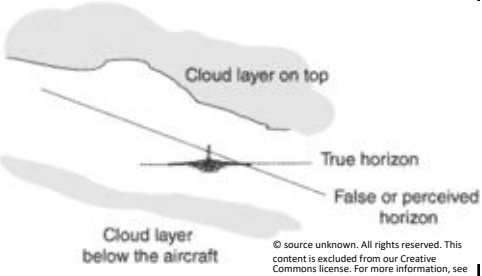


# Visual Illusions


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# Visual Illusions - Autokinesis

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- In the dark, a stationary light will appear to move about when stared at for many seconds
- Could cause loss of aircraft control in attempting to align it with the false movements of this light

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## Optical Illusions – Runway Illusions

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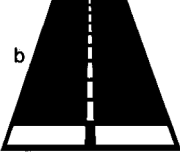
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a






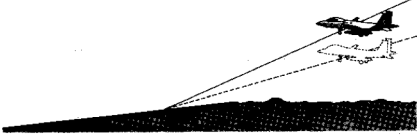
b






c





Source: Public Domain

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## Featureless Terrain Illusion

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- An absence of ground features, as when landing over water, darkened areas, and terrain made featureless by snow, can create the illusion that the aircraft is at a higher altitude than it actually is.
- The pilot who does not recognize this illusion will fly a lower approach.

[https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/spatiald\\_visillus.pdf](https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/spatiald_visillus.pdf)

[https://www.faa.gov/regulations\\_policies/handbooks\\_manuals/aviation/helicopter\\_flying\\_handbook/media/hfh\\_ch13.pdf](https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/helicopter_flying_handbook/media/hfh_ch13.pdf)

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## Optical Illusions

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- Water Refraction: rain on the windscreen can create the illusion of being at a higher altitude
- Haze: atmospheric haze can create an illusion of being at a greater distance and height from the runway
- Fog: flying into fog can create an illusion of pitching up
- Ground Lighting Illusions: lights along straight paths can be mistaken for runway and approach lights

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## Optical Illusion Prevention

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- Anticipate the possibility of visual illusions during approaches at unfamiliar airports
- Make frequent reference to the altimeter
- Use VASI or PAPI systems for visual reference



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## Motion Sickness

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- Caused by the brain receiving conflicting messages about the state of the body
- Symptoms include
  - General discomfort
  - Nausea
  - Dizziness
  - Paleness
  - Sweating
  - Vomiting
- Let your instructor know!

Good news: You will build up a tolerance. (Bad news: you may lose it if you don't fly for weeks.)

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## Stress

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- Stressors in aviation
  - Physical stress (noise or vibration)
  - Physiological stress (fatigue)
  - Psychological stress (difficult work or personal situations)
- Must monitor yourself and not fly if you are experiencing chronic stress
  - Performance falls off rapidly at certain chronic stress levels

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## Fatigue

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- Effects of fatigue include:
  - Degradation of attention and concentration
  - Impaired coordination
  - Decreased ability to communicate
- Physical fatigue results from:
  - Sleep loss
  - Exercise
  - Physical work
- Mental fatigue results from:
  - Stress
  - Prolonged performance of cognitive work



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## Fatigue

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- Acute fatigue can affect performance
  - Timing disruptions: pilot performs each component as though it were separate instead of integrated
  - Disruption of the perceptual field: concentrating attention in the center of vision and neglecting those in the periphery
- Prevent acute fatigue by:
  - Proper diet and adequate rest and sleep
- No amount of training or experience can overcome the detrimental effects of fatigue
  - Stay on the ground

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## Dehydration and Heat Stroke

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- Flying for long periods in hot summer temperatures or at high altitudes increases your susceptibility
- Some aircraft have a canopy or roof window that heats up in the sun

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## Alcohol and Drugs

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- Alcohol impairs the efficiency of the human body  
→ decreases performance
  - Pilots experiencing a hangover are still under the influence of alcohol according to the FAA
  - 14 CFR part 91 limits blood alcohol level and time since the last drink
- Both prescription and over-the-counter medications can degrade performance
  - 14CFR prohibits pilots from performing crewmember duties while using any medication that affects the body in any way contrary to safety

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## 91.17 - Alcohol or Drugs

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- 8 hours “bottle to throttle” (12 for most air carriers)
- Cannot operate under the influence
- Cannot operate with BAC  $\geq 0.04$  (0 for most air carriers)
- Intoxicated or drugged individual not allowed onboard
  - Exception 1: emergency
  - Exception 2: medical patient under care

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## 91.17 - Alcohol or Drugs

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- Must submit to alcohol test if requested by law enforcement
- FAA, with reasonable grounds, can request results of medical alcohol or drug tests performed within 4 hours of operation or attempted operation

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## 91.19 - Carriage of Drugs

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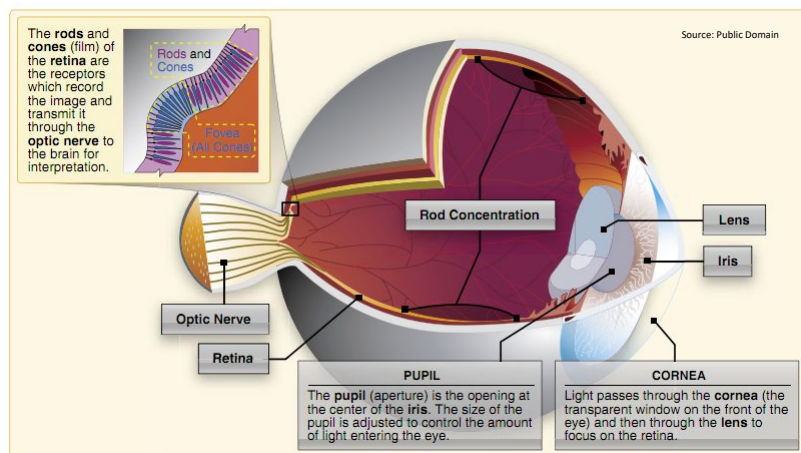
- Not allowed to carry drugs
  - Exception if allowed by Federal or State law

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## Vision

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- Most important sense for safe flight



- Empty-Field Myopia
  - With nothing specific to focus on (above the clouds) → eyes relax and focus at a range of 10 to 30 feet
  - Looking without seeing → dangerous for flying
  - Use a series of short, regularly spaced eye movements to search each 10-degree sector

Source: Public Domain



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## Aeronautical Decision-Making

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## Aeronautical Decision-Making

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- Decision-Making
- Hazards
- Risk
- Personal Checklists

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## Aeronautical Decision-Making (ADM)

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- Roughly 80% of aviation accidents related to human factors → many occur during landing (24.1%) and takeoff (23.4%)
- ADM – “Systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances”

Philosophy: Good judgment can be taught.

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## Crew Resource Management

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- Captains as lone heroes made a lot of bad decisions
- Airlines pioneered Crew Resource Management (CRM) in the 1980s. Adds the following:
  - First Officer (co-pilot)
  - Dispatcher (available via radio)
  - Air Traffic Controller
  - Maybe the flight attendants
- FAR 121.419 requires CRM

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## Single-Pilot Resource Management (SRM)

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Are you actually a Crew of 1? Consider:

- Instructor or pilot friend to help plan and dispatch flights beyond the local area
- Autopilot
- Air Traffic Controller
- Passenger right next to you

FAA emphasizes single-pilot GA, but turboprop, bizjet, and charter world is all Pilot Flying+Pilot Monitoring going from checklist to checklist. You can do the same with an instructor or pilot friend!

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## Good Decision-Making

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1. Identifying personal attitudes hazardous to safe flight
2. Learning behavior modification techniques
3. Learning how to recognize and cope with stress
4. Developing risk assessment skills
5. Using all resources
6. Evaluating the effectiveness of one's ADM skills

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## Hazards and Risk

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- Two defining elements of ADM
  - Hazard: Real or perceived condition, event, or circumstance that a pilot encounters
  - Risk: An assigned value to the potential impact of the hazard by the pilot
- Risk Management: “Part of the decision making process which relies on situational awareness, problem recognition, and good judgment to reduce risks associated with each flight”

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# Hazardous Attitudes

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- Attitudes affect the quality of decisions
  - Every pilot is subject to hazardous attitudes
  - Solution: Recognize the attitude, label it, and state the antidote

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NAME	DESCRIPTION	ANTIDOTE
Antiauthority	"Don't tell me..."	Follow the rules; they're usually right.
Impulsivity	"Do something quickly!"	Not so fast-Think first!
Invulnerability	"It won't happen to me..."	It could happen to me!
Macho	"I can do it."	Taking chances is foolish.
Resignation	"What's the use?"	I'm not helpless.

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<https://www.aopa.org/news-and-media/all-news/1999/september/flight-training-magazine/hazardous-attitudes>



# Assessing Risk

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Risk Assessment Matrix					
		Severity			
Likelihood		Catastrophic	Critical	Marginal	Negligible
Probable	High	High	Serious		
Occasional	High	Serious			
Remote	Serious	Medium		Low	
Improbable					

Source: Public Domain

- Likelihood of an event
- Severity of an event
- Mitigating risk

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## IMSAFE Checklist

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The *pilot* is responsible for determining whether he/she is fit for a particular flight

- I – Illness
- M – Medication
- S – Stress
- A – Alcohol
- F – Fatigue
- E – Emotion

Experienced single-pilot turboprop and light jet owners often take a co-pilot when using the plane for an all-day business trip. The co-pilot will be fresh for the return trip.

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## PAVE Checklist

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- PAVE checklist divides the risks of flight into four categories:

- P – Pilot-in-command (PIC)
- A – Aircraft
- V – enVironment
- E – External Pressures

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## PAVE Checklist (P&A)

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- PIC
  - Can use IMSAFE
  - Also need to look at experience, recency, and currency
  
- Aircraft
  - Specific aircraft
  - Type of aircraft

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## PAVE Checklist (V)

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- EnVironment
- Weather
  - Terrain
  - Airport
  - Airspace
  - Nighttime

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## PAVE Checklist (E)

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### External Pressures

- Need to get to scheduled event
- Must wait for late passenger (JFK, Jr. to MVY)
- Return plane to flight school
- Avoid missing work

Remember that airliners are deiced and fly above the weather. Even the best pilot in a Cessna 172 may need to wait an extra day or two.

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## The SRM Five “P” Check

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Scheduled review of 5 Ps during critical points: preflight, takeoff, cruise, descent, final

1. The Plan: the mission or task
2. The Plane
3. The Pilot: IMSAFE
4. The Passengers: may not understand the risks
5. The Programming: automation and avionics

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## Resources

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- FAA Pilot Handbook Chapter 17 (Aeromedical Factors)
- FAA Pilot Handbook Chapter 2 (Aeronautical Decision Making)

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## Summary

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- The newest airplanes are essentially products of the 1950s.
- Therefore, you are the weakest link.
- If you know that you won't be at your best, grab a co-pilot or CFI!

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