



AOA and AOCOPM Aerospace Medicine Spatial Disorientation

CAPT Kris Belland, MC, USN
COMMANDER NAVAL AIR FORCES
Force Surgeon





Background



- 1980-90** **USNA / PCOM / Gen Surgery NHO**
- 1990-95** **Flight Surgery / CVW-5 Japan / 14 Miramar CA**
- 1995-96** **Flight Training T-34 / 45, F/A-18 (Line and Staff Officer)**
1,500 112 25 4.5yrs 3 Combat Cruises
- 1997-02** **NSAWC / TOPGUN / USAF AWC**
Performance Maintenance, CBRNE, DEW, Childhood Cluster
- 2002-05** **USS KITTY HAWK SMO (OIF) / THIRD Fleet Surgeon**
Senior Operational Screened
- 2009-13** **COMNAVAIRFORCES Force Surgeon**
C4F NAVSOUTH Surgeon Operation Unified Response
C7F LNO To CNFJ Operation Tomodachi
Family Practice, Preventive Medicine – Aerospace Medicine
MPH, MBA, MSS, CMBA, CPE, FAsMA



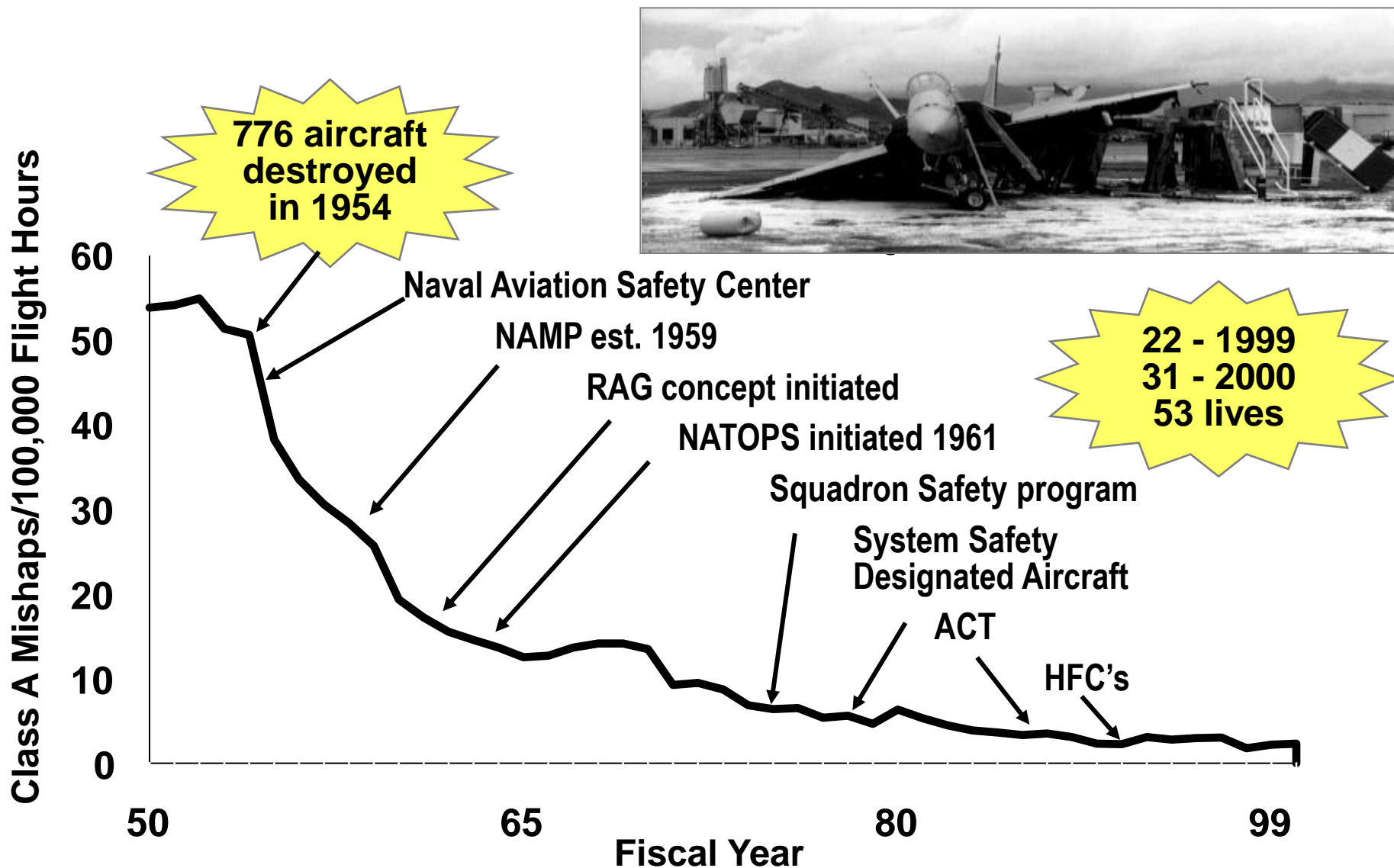
Terminal Objectives



- **Sensory System Objectives**
 - Be familiar with the three primary sensory systems and how they interact to provide orientation information to the brain
- **Spatial Disorientation Objectives**
 - Be familiar with spatial disorientation; the three types, prevention of and recovery from spatial disorientation.
- **Sensory Illusions Objectives**
 - Be familiar with sensory illusions common to the aviation environment
- **PRESENTATION DOES NOT REPRESENT THE USN OR DOD BUT ARE THE OPINION OF THE AUTHOR**



Naval Aviation Mishap Rate

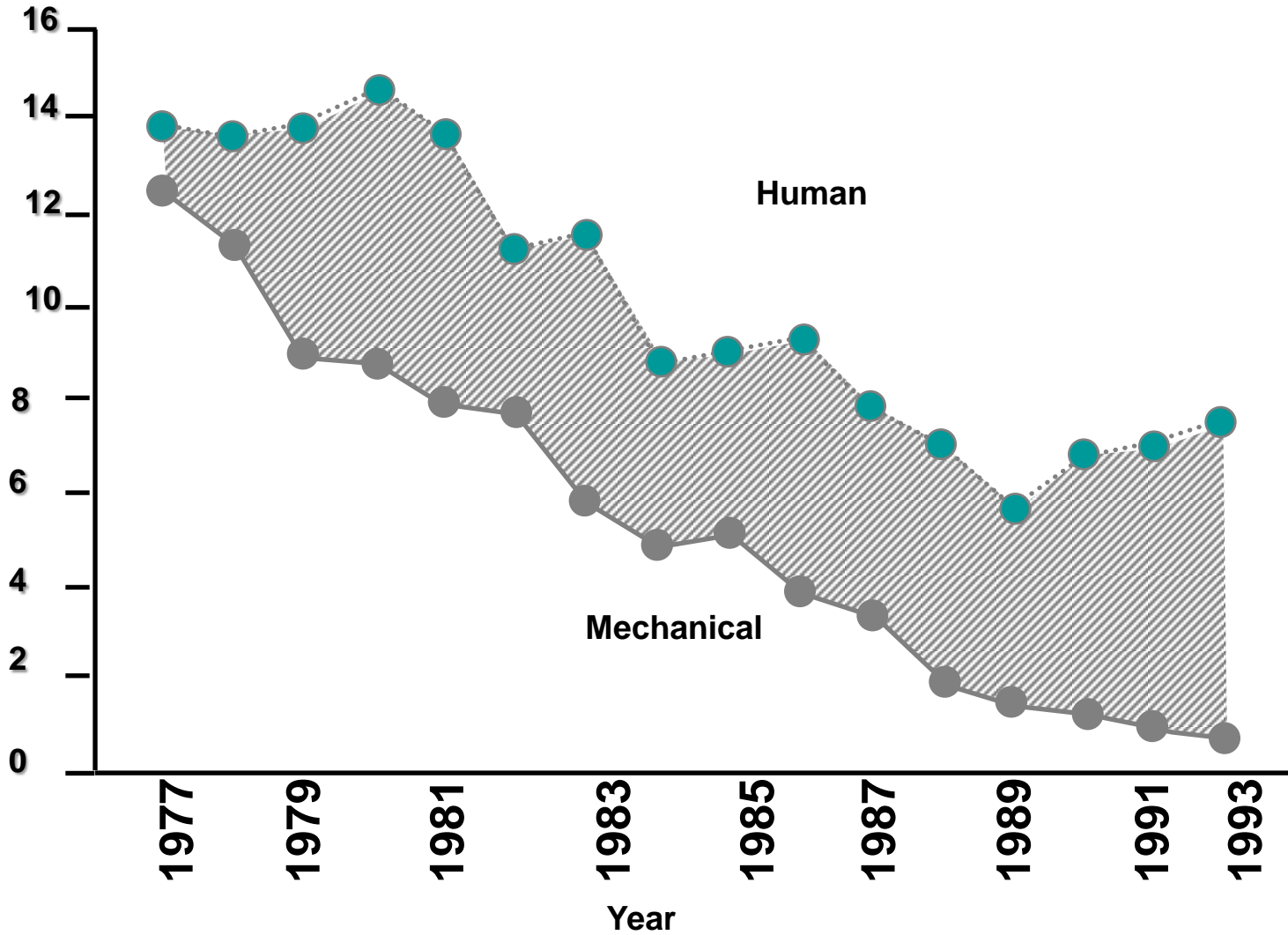




Navy / Marine Corps Mishaps CY 1977-93



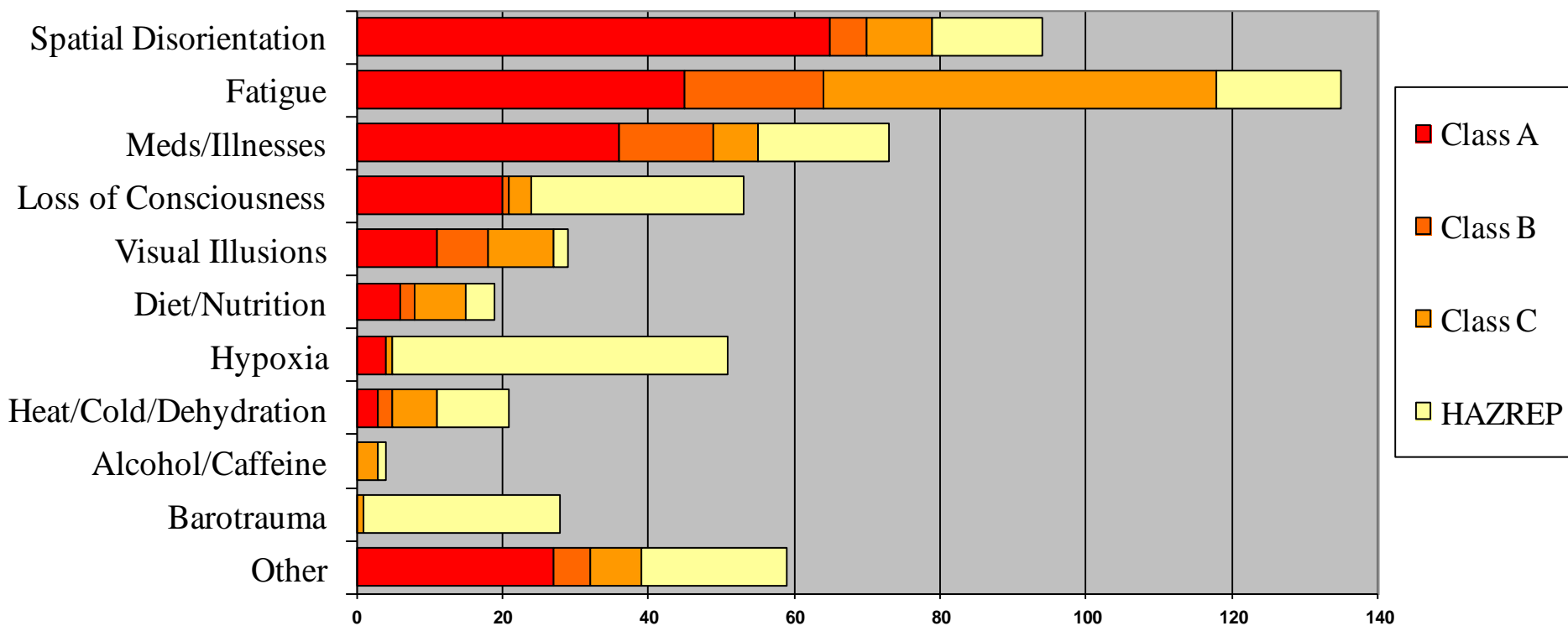
Class A, B, & C Mishaps/100,000 Flight Hours





Aeromedical Causal Factors

Reported in Mishaps & HAZREPS



CAPT L. Mandel; NAVSAFECEN data from Mr. John Scott; FY's 1990-2011



Aeromedical Significance



- Good news Downward Overall Trend
 - Plenty of room for improvement
- Bad news
 - Still lose too many lives in DoD aviation mishaps
 - 70-90% of mishaps are human errors
 - Cost 513 Million Dollars FY 2006 (USN only)
 - 10-12 Billion Accident and Injury



Orientation

Visual

80%

Vestibular

15%

Proprioceptive

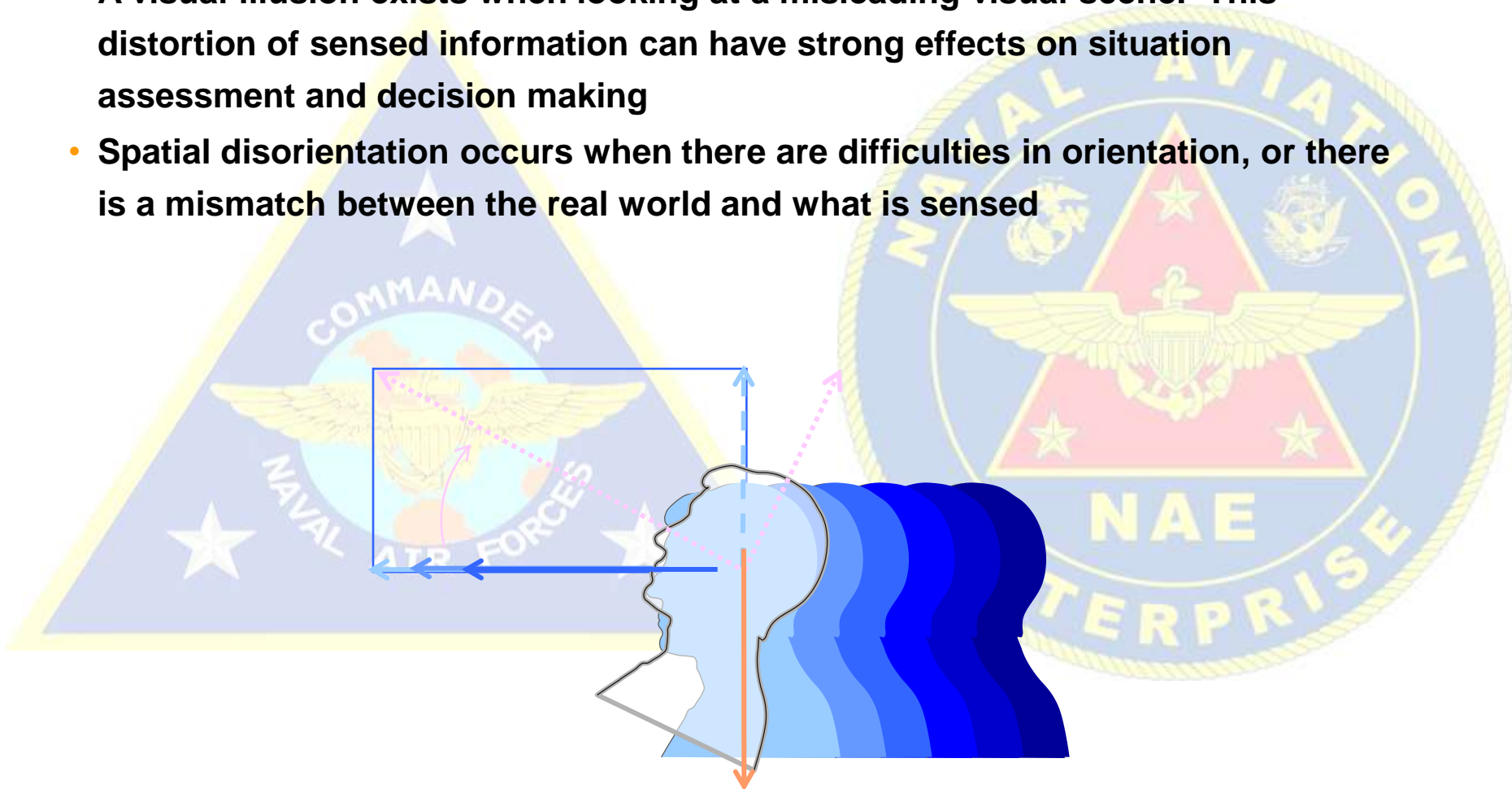
5%



Spatial Disorientation

Visual illusions and spatial disorientation have contributed to many aircraft accidents; their effects are most pronounced at night and in instrument meteorological conditions (IMC)

- A visual illusion exists when looking at a misleading visual scene. This distortion of sensed information can have strong effects on situation assessment and decision making
- Spatial disorientation occurs when there are difficulties in orientation, or there is a mismatch between the real world and what is sensed

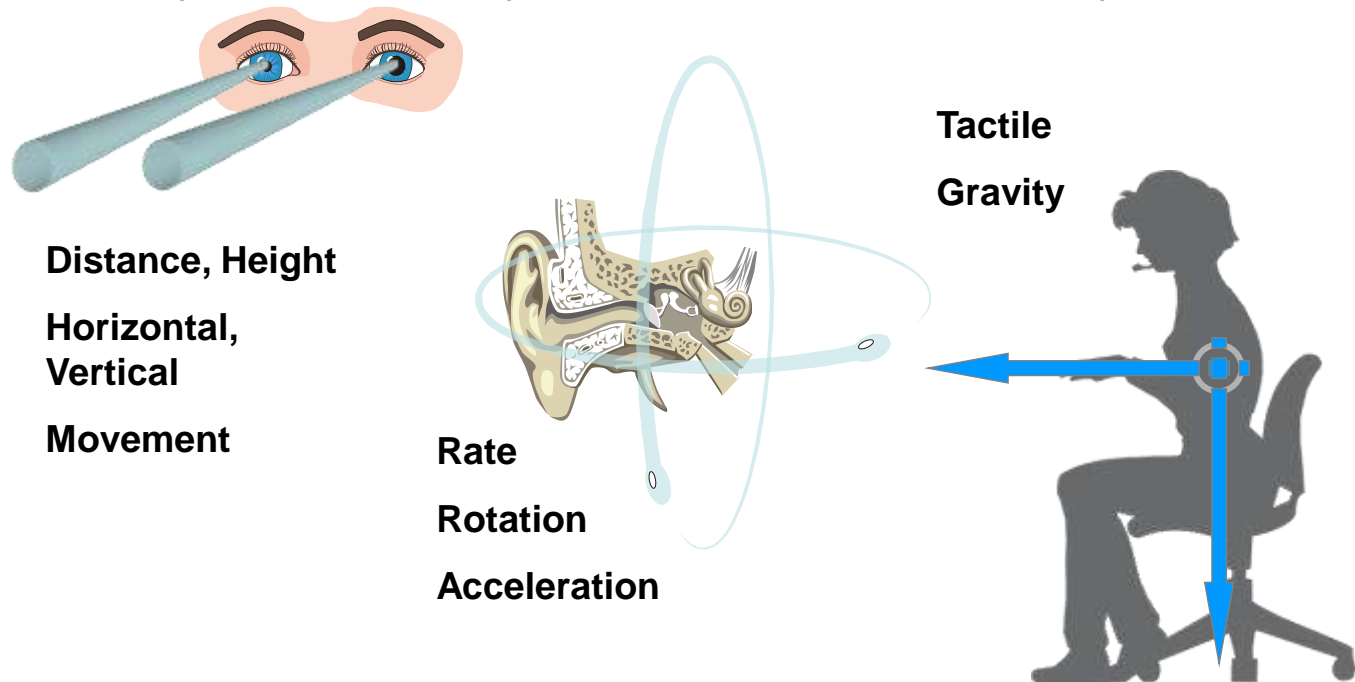




Spatial Disorientation



- The body has five senses: vision, hearing, touch, smell and taste.
- The sensory inputs that provide orientation and balance are the eyes, inner ear (vestibular), and tactile (motion or position) systems; they work simultaneously.

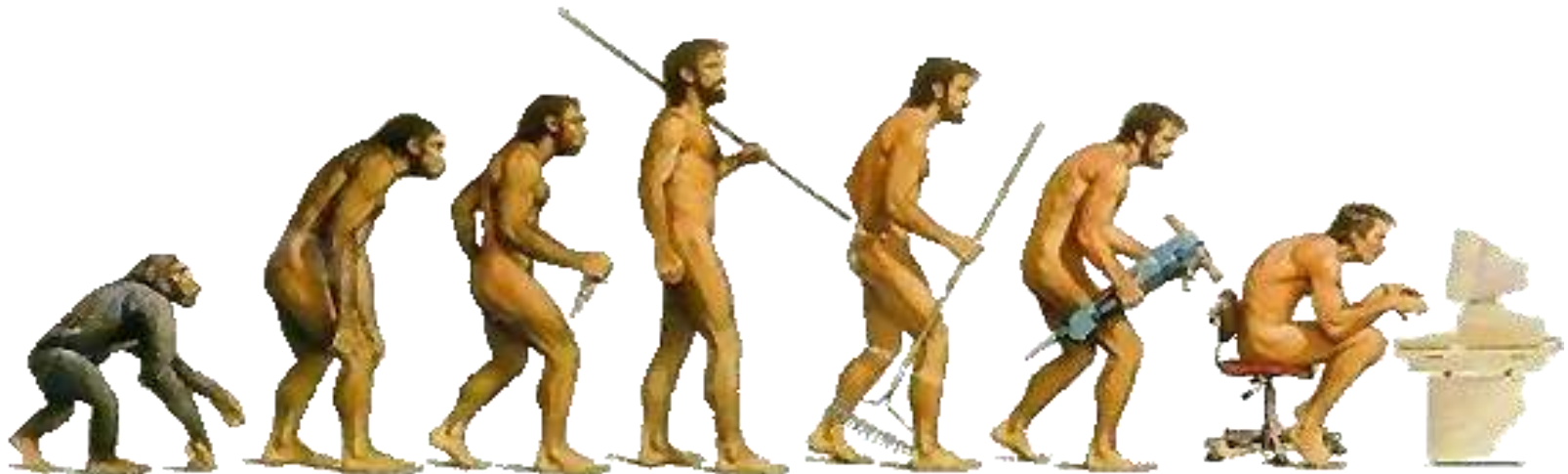




Spatial Disorientation



- Pilots can suffer from illusions of orientation in many ways, e.g. the misinterpretation of visual information; vision is the most important contributor to the perception of orientation.
- Other contributors are the vestibular system (inner ear) and the somatosensory system (pressure and position nerve receptors distributed throughout the body). These can produce spatial disorientation.
- Errors of perception (disorientation) are 'normal' sensations. The human equilibrium system is designed to function on the earth, to chase animals..., not to fly aircraft. Humans are not designed to fly.

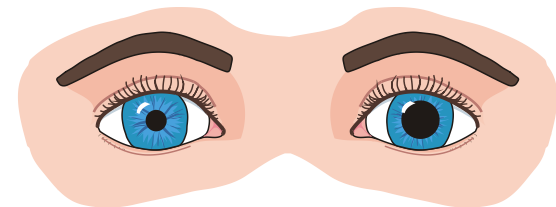




Vision



- The visual system consists of central and peripheral vision. Vision is the dominant sense for orientation when good visual cues are present, then attention to the other senses is easily and often suppressed.
 - Central vision allows us to perceive images clearly, it is the basis of judgments of distance and depth (relative distance).
 - Peripheral vision provides orientation. It is the primary mode for detecting our own motion or the motion of other objects around us. it provides orientation information if information from the inner ear is unavailable.
- Visual orientation requires perception, recognition and identification; people must determine their position (the situation) by understanding where other objects are in relation to themselves.





Visual system

Central/Focal

Conscious

Active Attention

Easily distracted

Difficult to deceive

Great detail

Object recognition

Peripheral/Ambient

Subconscious

No attention

Not distracted

Readily deceived

General information

Identify Motion

Depth Perception and Distance Estimation

- 2 forms of cues:
 - Binocular
 - Monocular



Binocular



- Differing retinal images between two eyes
- Effective up to 200m

Monocular

• **Conscious and subconscious cues: Learned by experience**

-Illumination perspective

-Texture or gradient

-Interposition

-Retinal imaging size

-Motion parallax

-Geometric perspective



The judging of distance and the perception of motion in the visual field

Retinal Image Size



Image size: bigger = closer

Object Associations: Compare known to unknown

Motion Parallax

- Ability to see how fast something is moving across the retina
- Distance between object and observer important
- Near objects move rapidly, far move slow



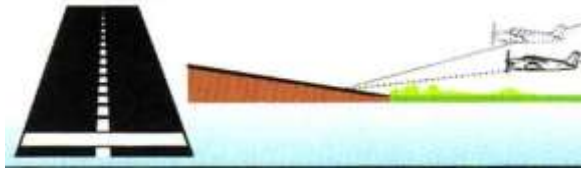


Geometric Perspective:

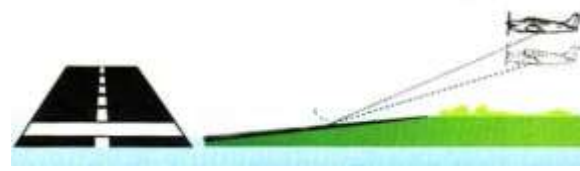
Lines will converge with distance

Visual Illusions - runway

- **Perspective Illusions** may change (increase or decrease) the slope of your final approach. They are caused by upsloping or downsloping runways, upsloping or downsloping final approach terrain and runways with different widths



upsloping runway may produce the illusion of a steep approach.



downsloping runway may produce the illusion of a shallow approach.



upsloping terrain may produce the illusion of a shallow approach.



downsloping terrain may produce the illusion of a steep approach.

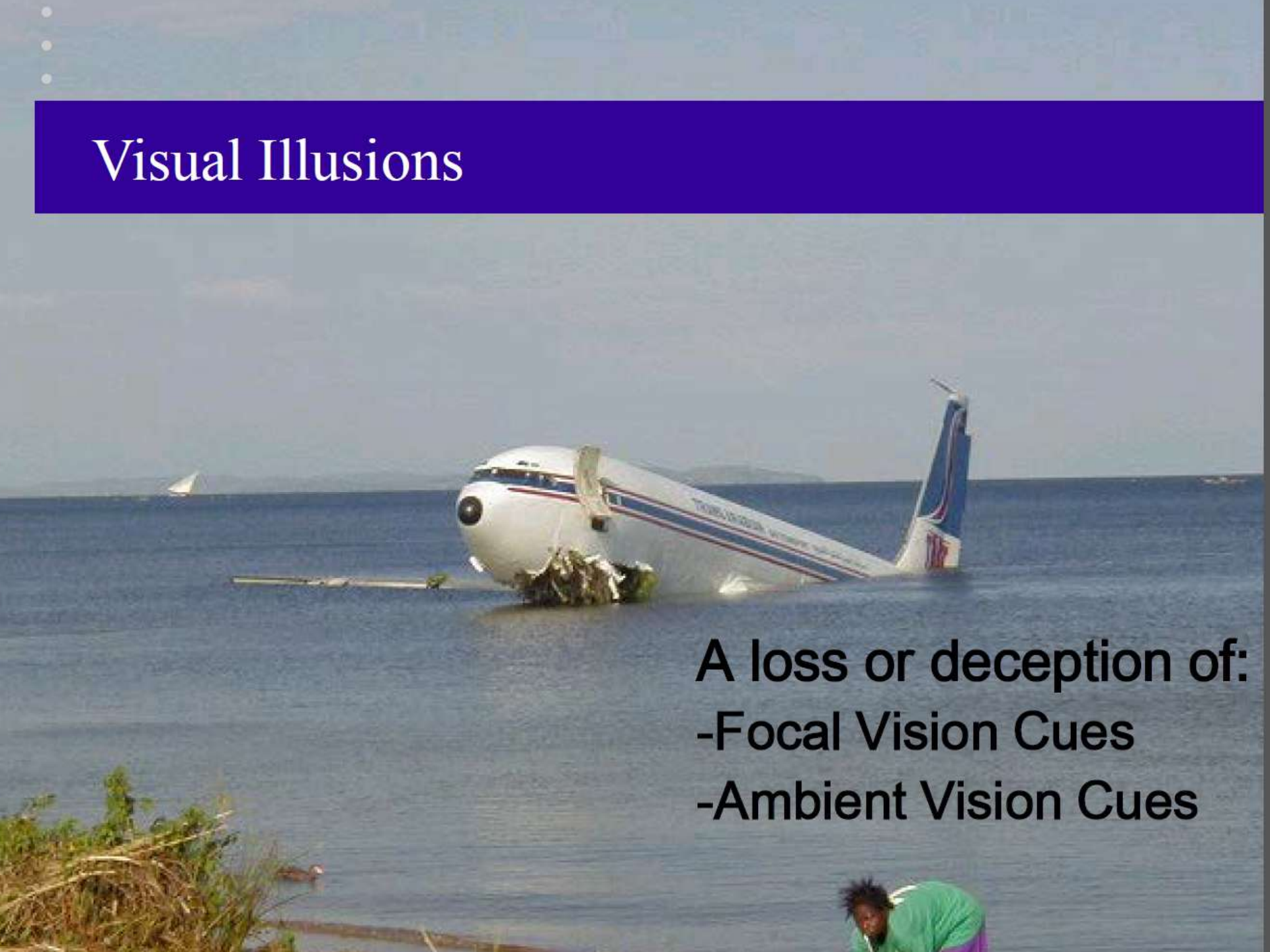


a narrow runway or long runway may produce the illusion of a steep approach.



a wide or short runway may produce the illusion of a shallow approach.

Visual Illusions



A loss or deception of:
-Focal Vision Cues
-Ambient Vision Cues

Avoiding Constancy Illusions

- Know the size and shape of the objects you are flying over
- Brief geographic features
- Communicate
- **ALWAYS cross-check your instruments!**



Ambient Illusions

- Vection illusions
- False horizons
- White-out/brown-out
- Black-hole



Illusionary Ambient Cues

Linear Vection



Angular Vection

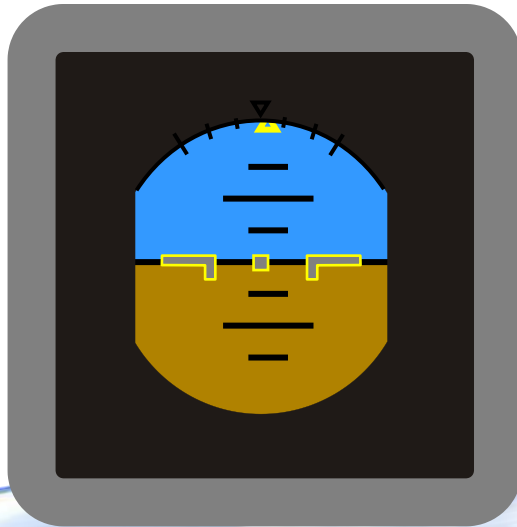




Visual Illusions – False Horizon



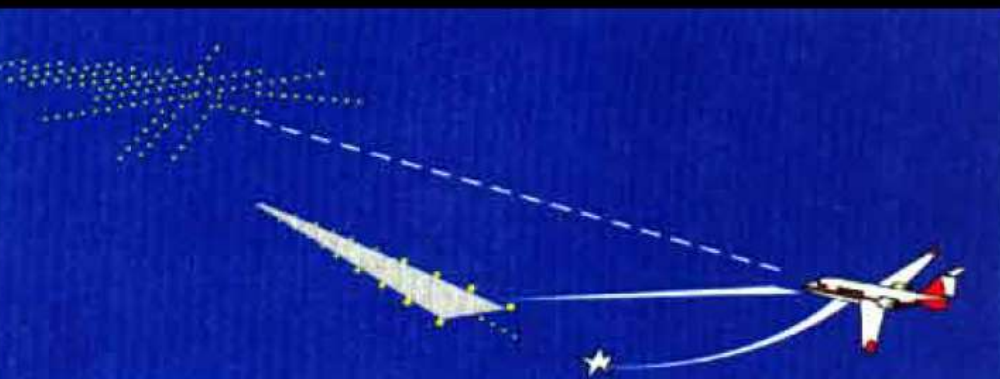
- **The false-horizon illusion occurs when the pilot confuses cloud formations with the horizon or the ground. A sloping cloud layer may be difficult to perceive as anything but horizontal if it extends for any great distance in the pilot's peripheral vision. A cloudbank below may be perceived to be horizontal although it may not be horizontal to the ground, resulting in the pilot perceiving a banked attitude.**



Make the instruments read right !

Rely on the flight instruments – never on your perception. Ignore your internal instruments.

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- Absent Ambient Cues: The Black Hole Illusion

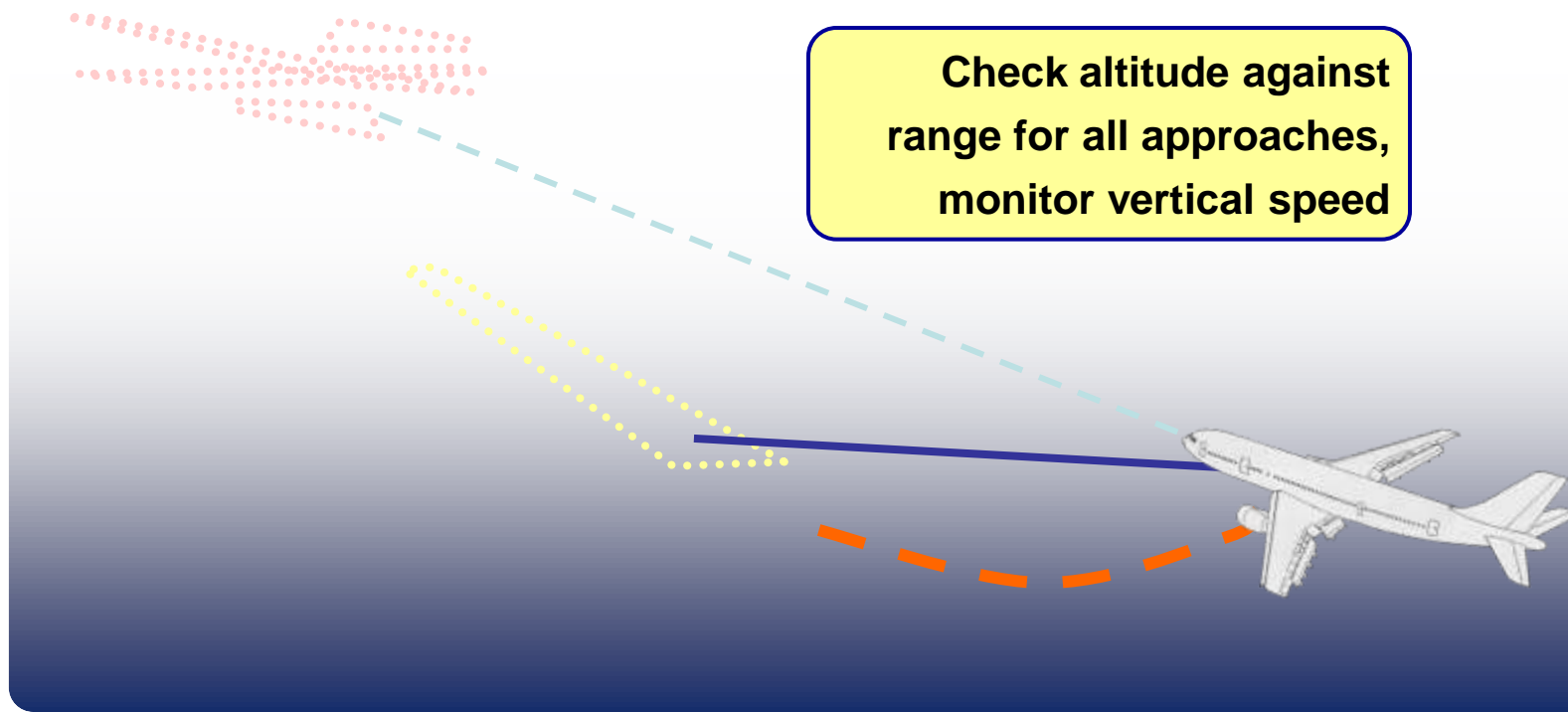




Visual Illusions – Black Hole



- The ‘black hole’ approach illusion occurs when approaching a runway at night or in poor visibility with no lights before the runway and with city lights or rising terrain beyond the runway. These conditions may produce the visual illusion of a high-altitude final approach. If you believe this illusion, you may respond by descending below the normal approach slope.



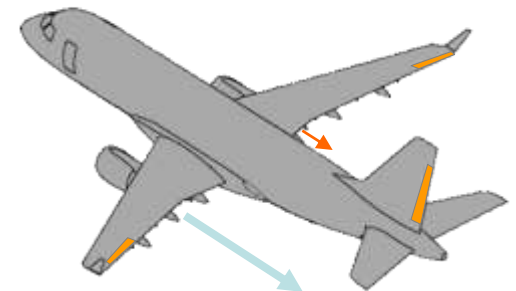


Force illusions



- Pilots are taught to fly the aircraft in trim. Conventional control systems use a combination of force and position to provide feedback to the pilot.
 - Trimming the pitch control is routine, trim varies with speed.
 - Lateral trim seldom varies, but an out-of-balance force due to fuel or configuration asymmetry disturbs the normal force/position relationship. In these circumstances, do not judge the position of control neutral position on force alone.
 - Rudder trim is used with asymmetric thrust, but the force and position of the rudder controls will vary with both change of thrust and airspeed. Beware of potential false control position sensations due to residual untrimmed forces.

**Scan all instruments and believe their readings.
Do not make control inputs based on your
'feelings.'**





Perception

Waterfall Effect

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Where's the Horizon?

•If the ambient vision acquires a strong line, it will frequently take it to be the horizon





Absent Ambient Cues: Brownout

AERIAL PERSPECTIVE

“Atmospheric Induced Visual Problems”



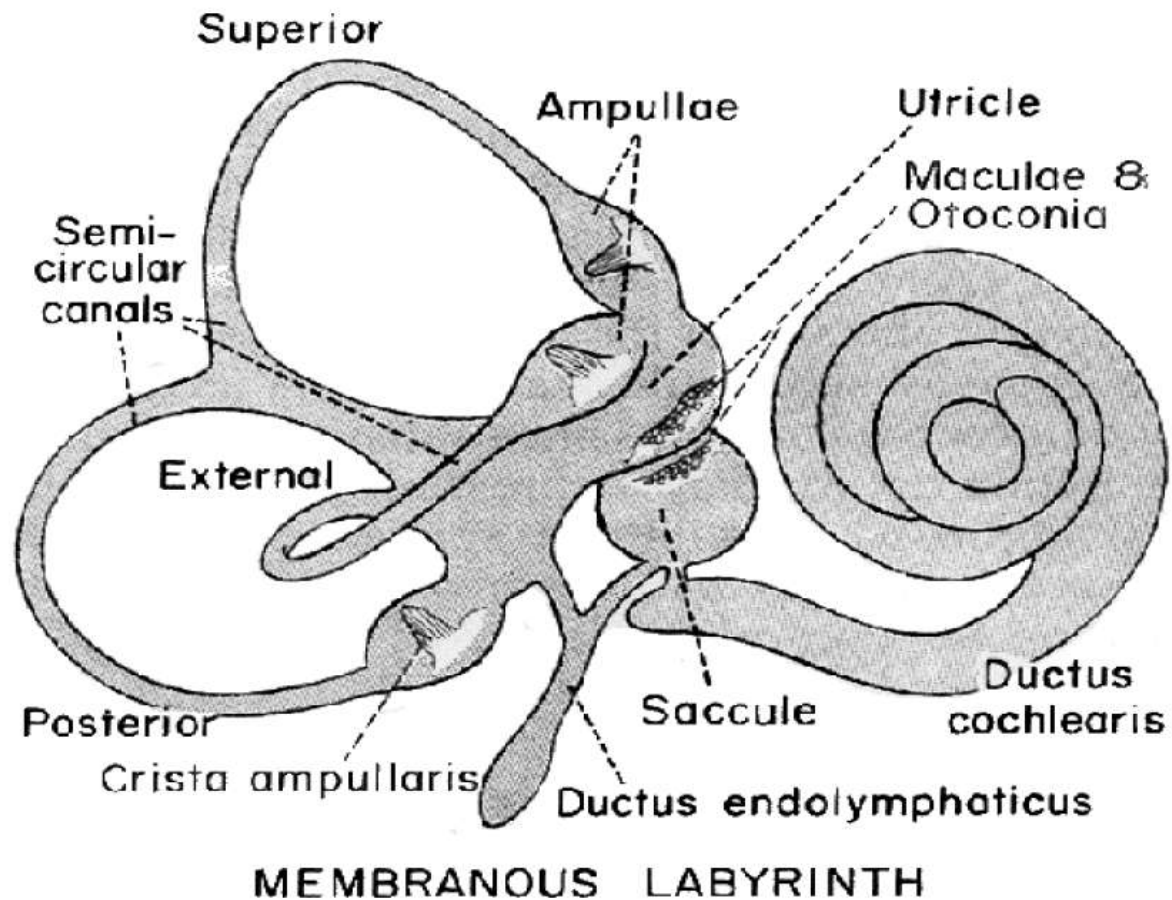
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Vestibular System

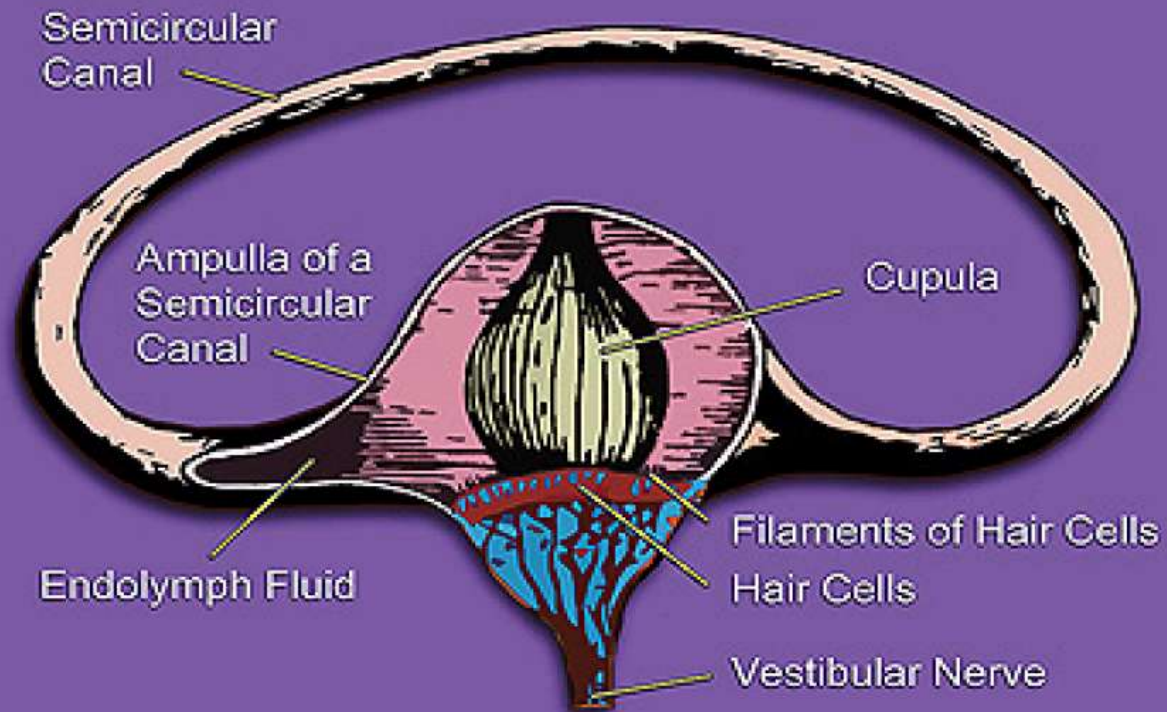
Semicircular Canals
Angular Acceleration

Otolith Organs
Linear Acceleration

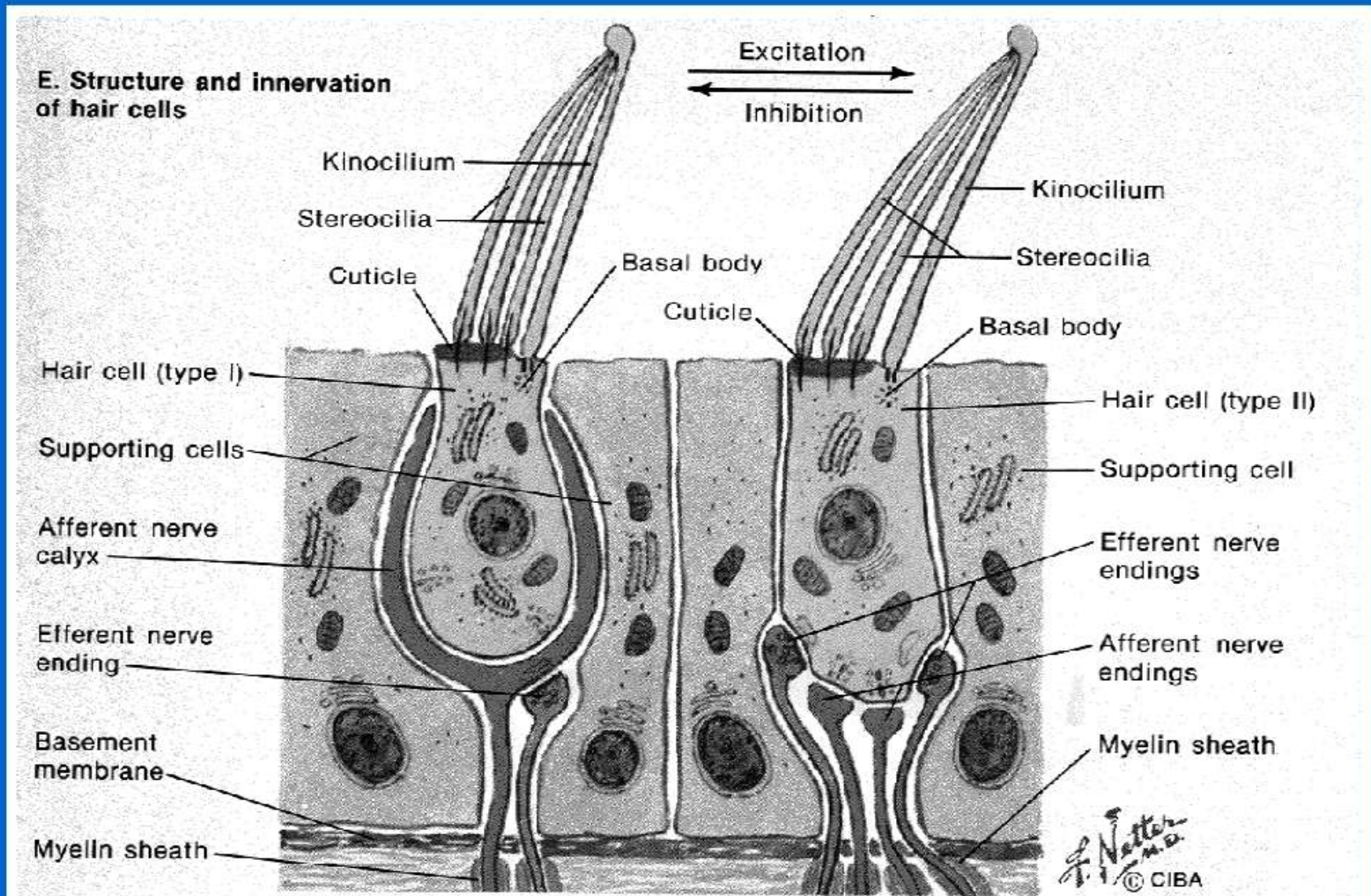
The Vestibular Apparatus



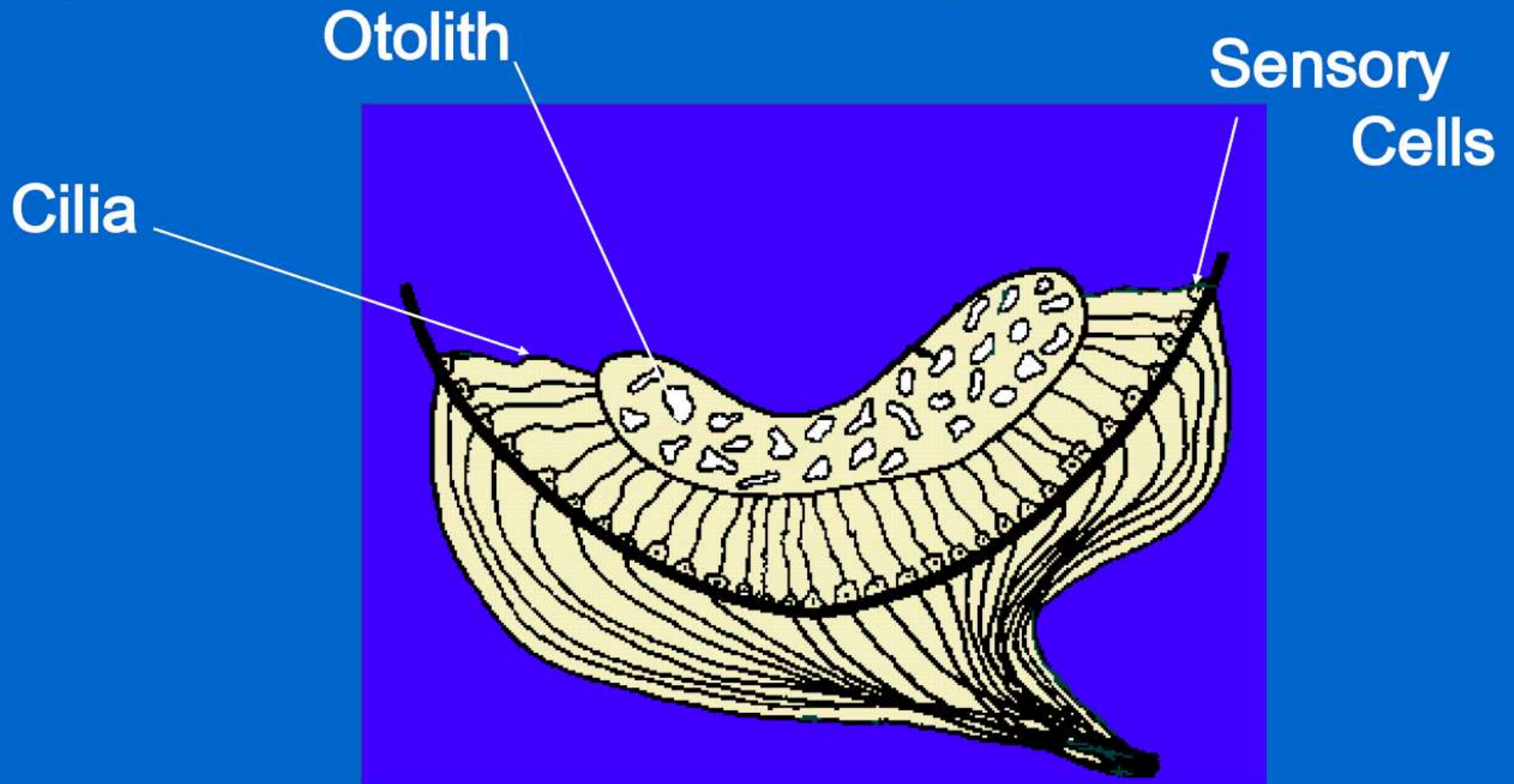
Semicircular Canal



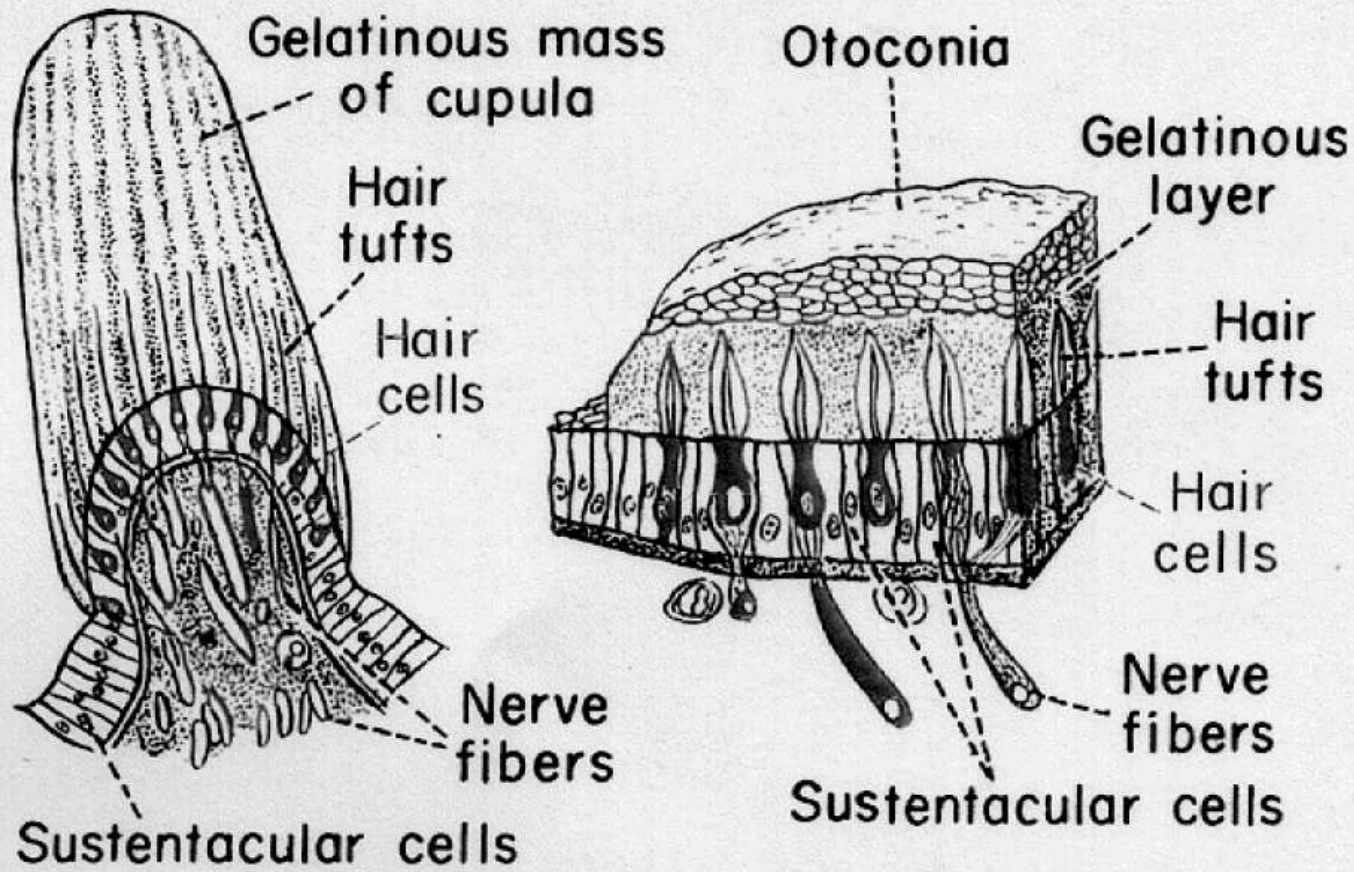
The Tiny Accelerometer



Otolith Organ



Otolith Organ



CRISTA AMPULLARIS AND MACULA

Proprioceptive System

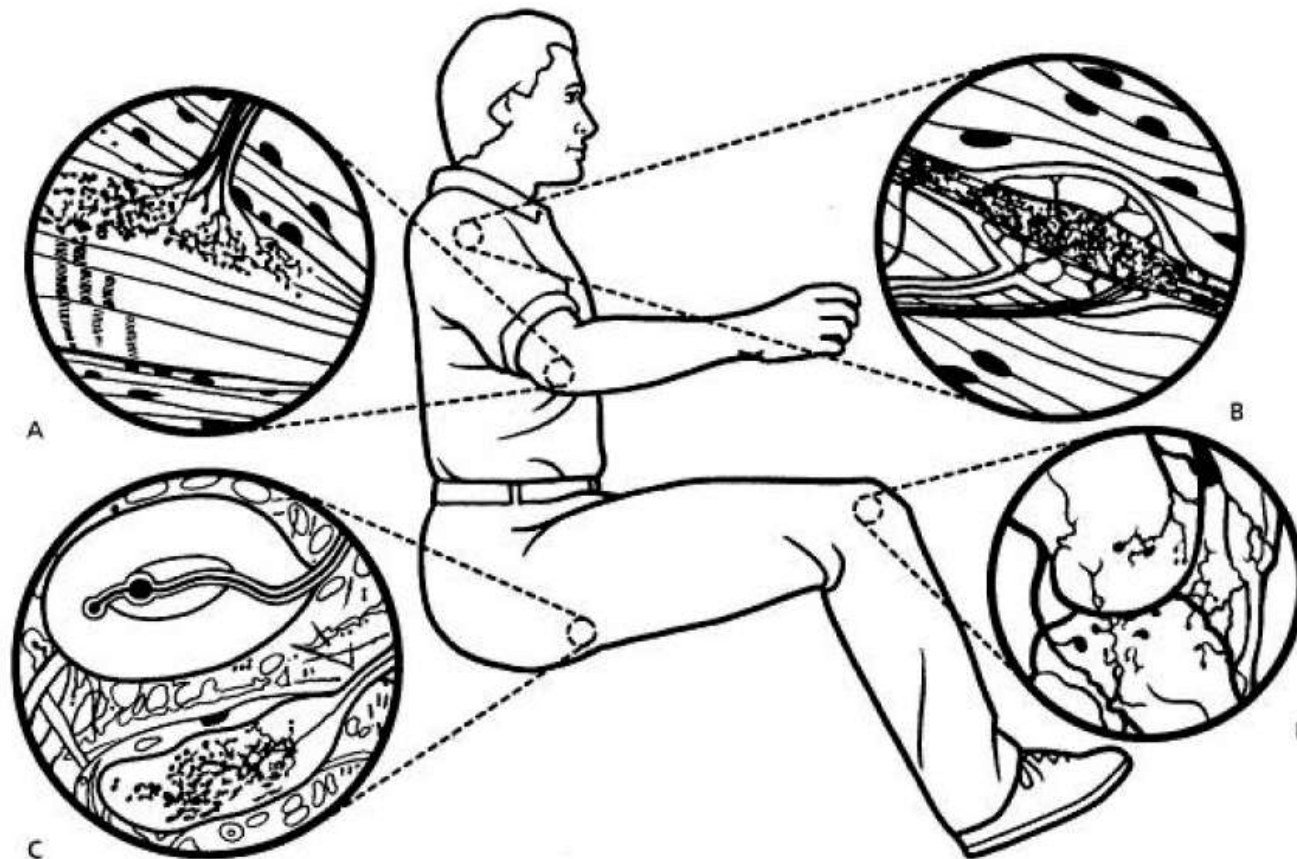
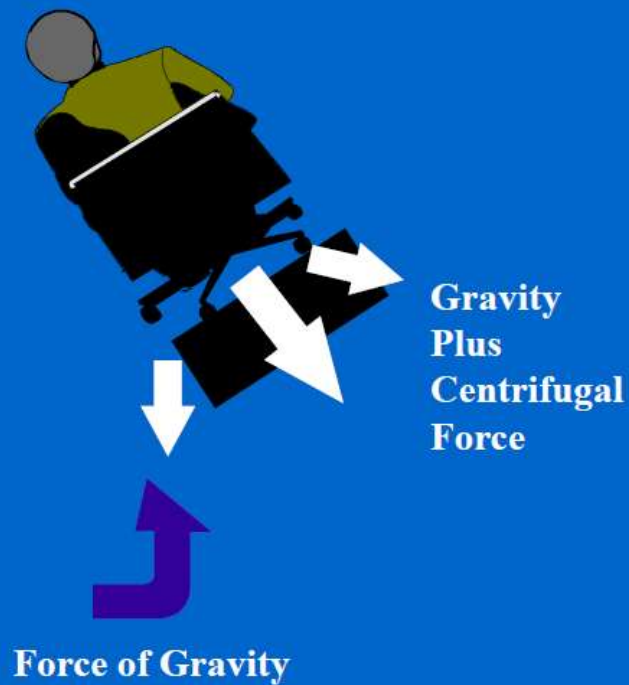


FIGURE 8.13. Some of the nonvestibular proprioceptive and cutaneous exteroceptive receptors subserving spatial orientation. **A:** Muscle spindle, with central afferent (sensory) and more peripheral efferent (fusimotor) innervations. **B:** Golgi tendon organ. **C:** Lamellated, spray-type, and free-nerve-ending joint receptors. **D:** Two of the many types of mechanoreceptors found in the skin: lamellated Pacinian corpuscles and spray-type Ruffini corpuscles.

The Seat-of-the-Pants Sense



Illusions

Somatogyral Illusion

Oculogyral Illusion

Somatogravic Illusion

Oculogravic Illusion

Turning Illusion and False Climb Illusion



There are two main causes of spatial disorientation:

The turning illusion (somatogyral illusion)

- A false sensation of rotation or absence of rotation
- Any discrepancy between actual and perceived rate of rotation
- It originates in the inability of the semicircular canals to register accurately prolonged rotation (> 30 seconds), e.g. banking during holding pattern

The false climb illusion (somatogravic illusion)

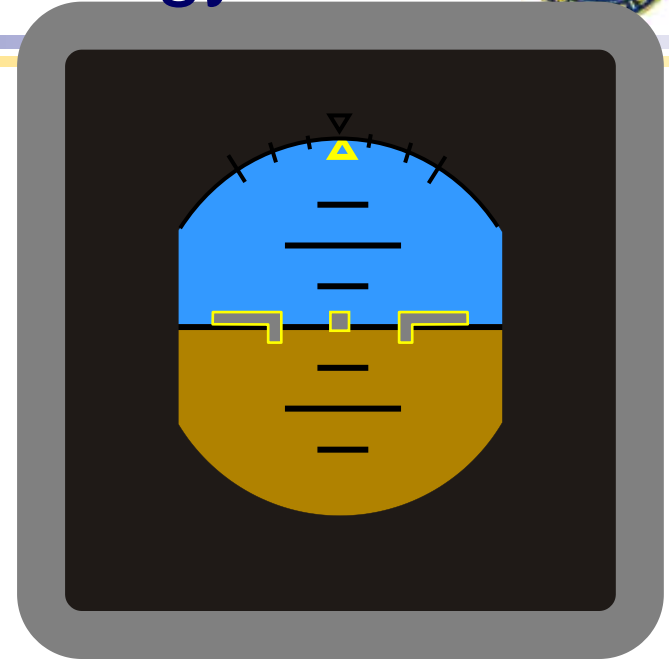
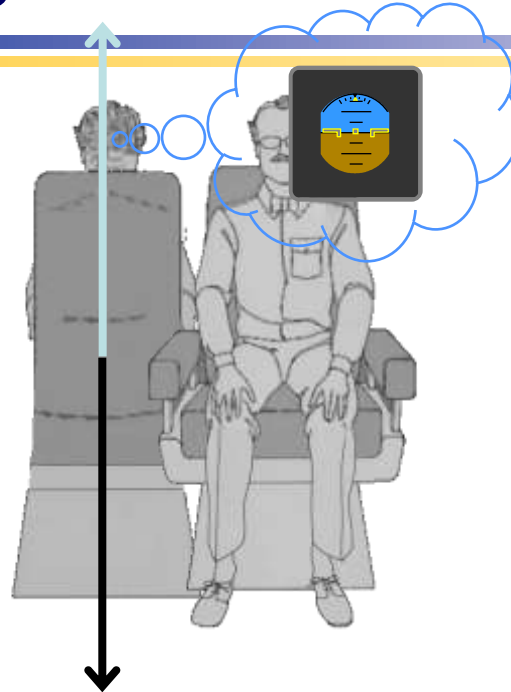
- A false sensation of body tilt that results from a longitudinal acceleration.
- A discrepancy between actual and perceived pitch angle
- It occurs during longitudinal acceleration

Somatogyral Illusion

- The false sensation of turning (or lack of turning) due to the inherent problems associated with semicircular canal function.



Turning Illusions - Somatogyral



- **Leans**

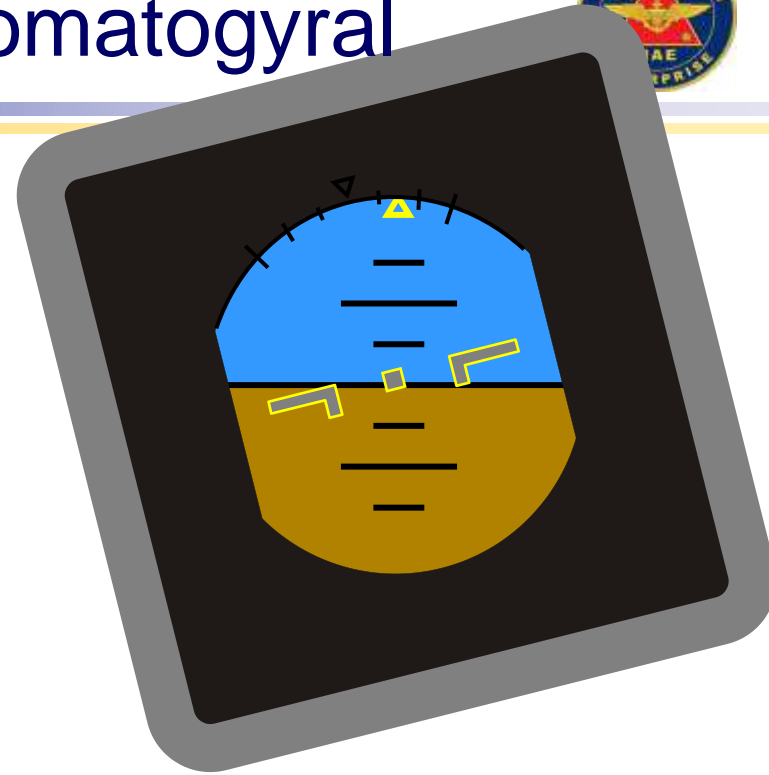
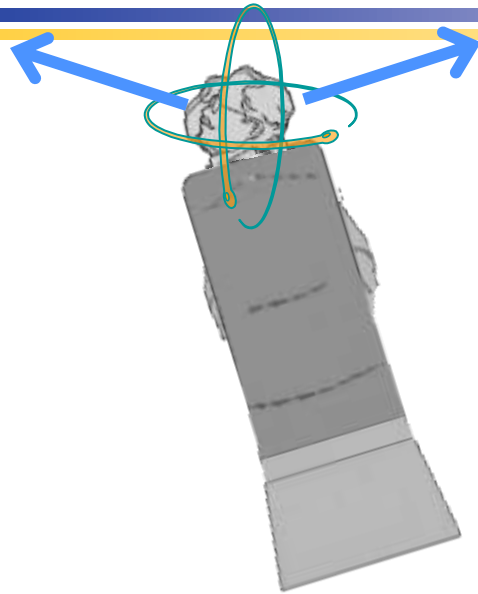
The most common form of spatial disorientation is the leans. This illusion occurs when the pilot fails to sense angular motion. With a slow rate of roll, the pilot may not perceive that the aircraft is banked. He may feel that his aircraft is still flying straight and level although the attitude indicator shows that the aircraft is in a bank.

Make the instruments read right !

Rely on the flight instruments – never on your perception. Ignore your internal instruments.



Turning Illusions - Somatogyral



- **Coriolis Illusion**

This illusion occurs in a prolonged turn. If the pilot initiates a head movement in a different geometrical plane, the semicircular canals sense a turn in all three canals creating a new perception of motion in three different planes of rotation at once: yaw, pitch, and roll. The pilot experiences an overwhelming head-over-heels tumbling sensation.

Make the instruments read right !

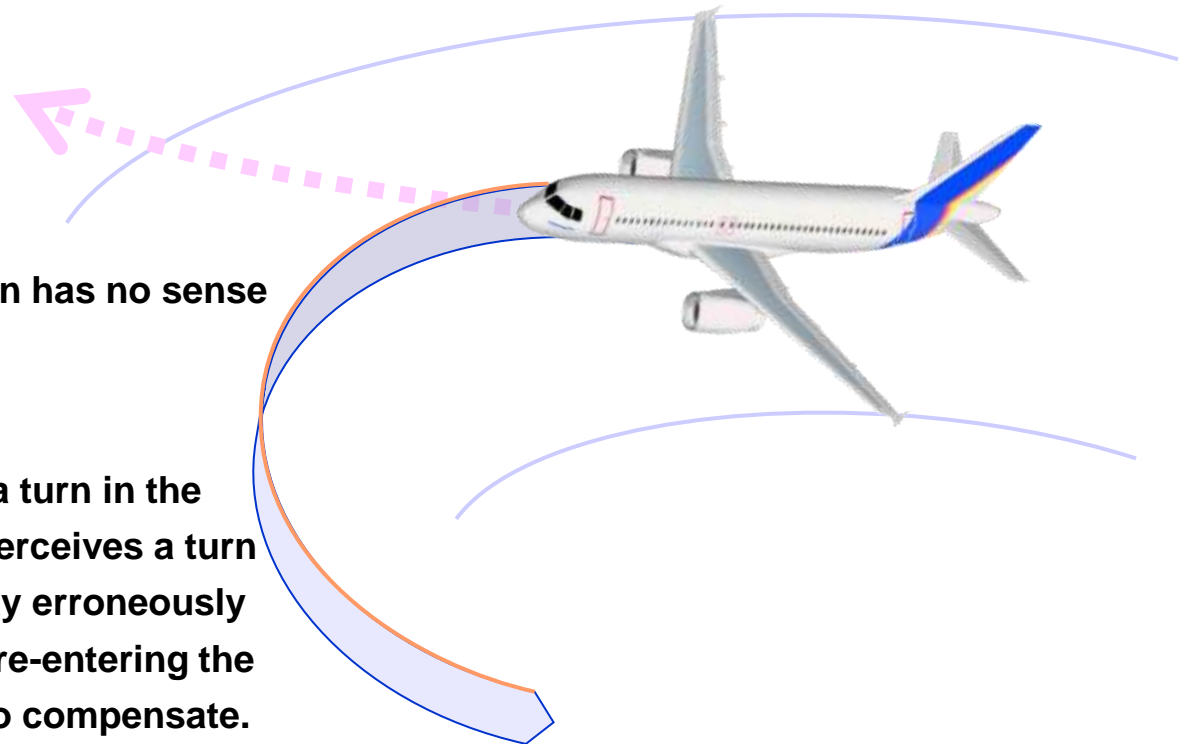
Rely on the flight instruments – never on your perception. Ignore your internal instruments.



Turning illusion



- It originates in the inability of the semicircular canals (inner ear) to register accurately prolonged rotation (> 30 seconds), e.g. banking during holding pattern).



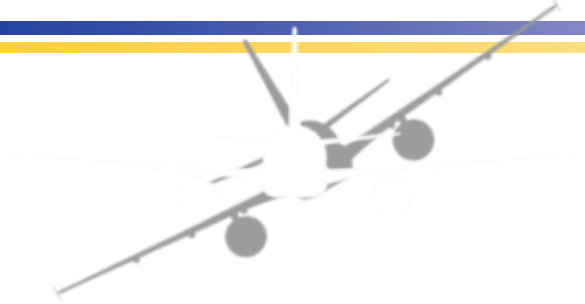
After approx 30 seconds, the brain has no sense of turning any more.

If the aircraft is now straightened, the brain senses a turn in the opposite direction. If the pilot perceives a turn in the opposite direction, he may erroneously correct for this illusory turn by re-entering the original turn and overbanking to compensate.

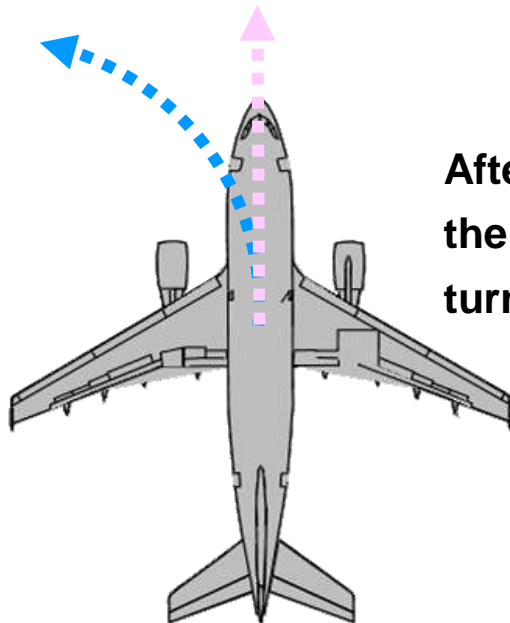
Additionally, the pilot's instrument scan may be disturbed, and that disables clear reading of the solely reliable instruments.



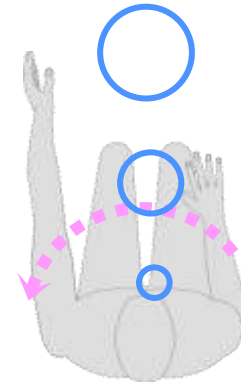
Turning illusion



The aircraft makes a sustained turn.

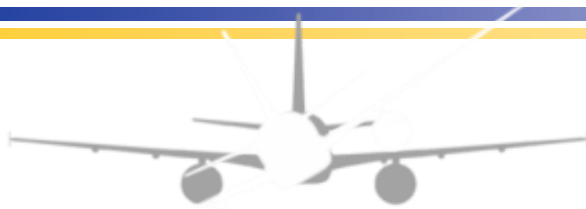


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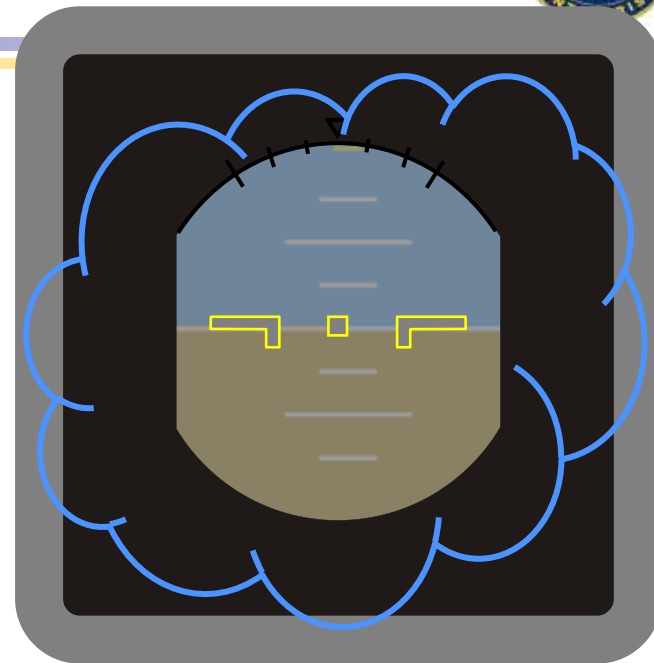
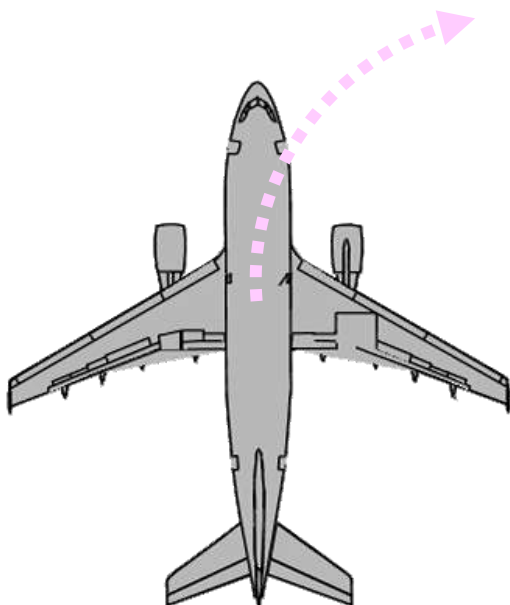




Turning illusion



If the trajectory of the aircraft is now straightened, the brain senses a turn in the opposite direction.



The pilot perceives a turn in the opposite direction.

He may erroneously correct for this illusory turn by re-entering the original turn and overbanking to compensate, so that he perceives stable flight.



Turning illusions - defenses

'Make the instruments read right!'
Rely on the flight instruments
– never on your perception.
Ignore your internal
instruments.



If your vision is disturbed – look at and concentrate on a nearby fixed point on the instrument panel.

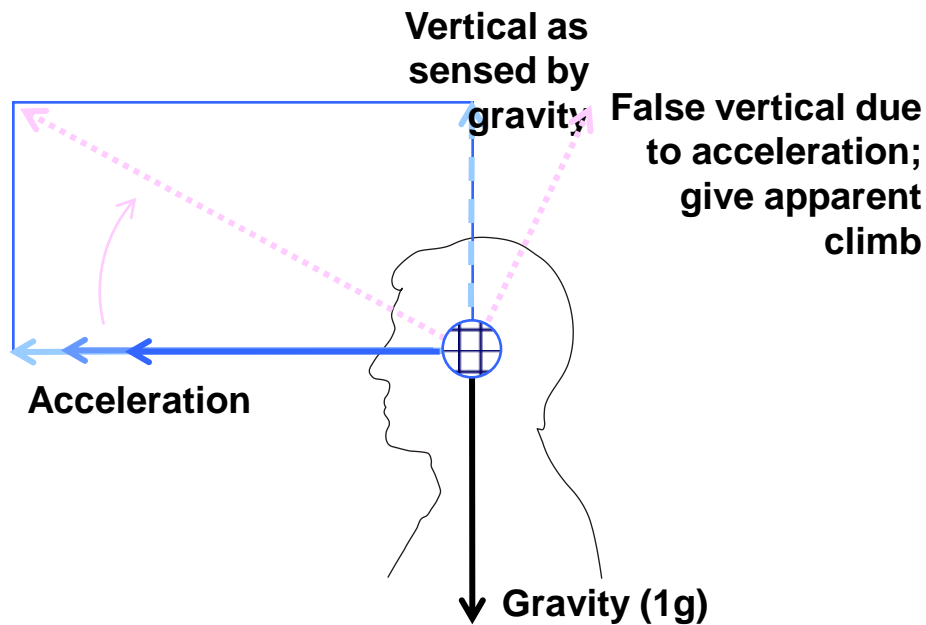
Remember that sustained rotations are misperceived by the equilibrium system as a false turn.



False Climb illusion (Somatogravic illusion)



- This illusion is a false sensation that the body has tilted due to a longitudinal acceleration.
- The pilot thinks the aircraft is climbing, but the aircraft pitch attitude is level or at a lower attitude than perceived.





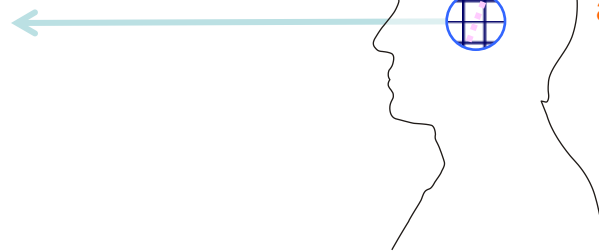
False Climb illusion



During an acceleration, the pilot thinks the aircraft is climbing, but the aircraft pitch attitude is at a lower attitude than perceived.



Acceleration



False vertical due to acceleration; gives apparent climb

Avoid the tendency to push forward. Concentrate on the attitude indicator.

Oculogyral Illusion

- The illusion that the visual field is moving (spinning).
- Caused by semi-circular canal function.
 - The vestibulo-ocular reflex can produce an exaggerated nystagmus
- Reinforces a somatogyral illusion.

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Somatogravic Illusion

- A false pitch change sensation resulting from a linear acceleration.
- Inherent limitations of the otolith organs.
- Proprioceptors can contribute to this illusion.



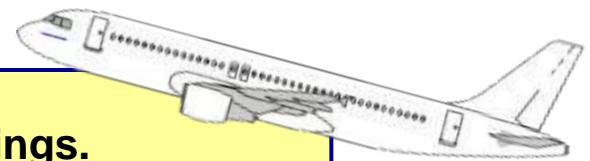
False Climb illusion during Go Around



- The false climb illusion of a 'nose-up' sensation during an acceleration may occur during go around or after takeoff; any erroneous correction by the pilot to push the controls forward could lead to a hazardous situation.
- An aircraft accelerating from 170 to 200 knots over a period of 10 seconds just after takeoff generates + 0.16G acceleration on the pilot. This corresponds to a sensation of 9 degrees 'nose up' attitude change.
- When no visual cues are present, follow the **INSTRUMENTS**, and do not push the nose down.

Scan all instruments and believe their readings.

Do not make control inputs based on your 'feelings.'



Oculogravic Illusion

- The visually apparent movement of a fixed object resulting from a change in the net gravitational force.
- The object will appear to move down during a deceleration and up during an acceleration.
- Results from trying to maintain fixation during a vestibulo-ocular reflex.

Spatial Disorientation Classification

Type I Unrecognized

Type II Recognized

Type III Incapacitating



SD Definition: A failure to sense correctly a position, motion, or attitude of the aircraft or of oneself within the fixed coordinate system provided by the surface of the earth and the gravitational vertical.

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Factors Affecting SD

Physical factors:

Weather, Time of Day, Mission Duration, Type of Mission

Physiological factors:

Illness, Self-Medication, Alcohol, Fatigue

Other factors:

Experience, Mission Preparation, Recency of Experience

Flight conditions likely to cause SD

- Instrument flight
- NVG flights
- Night unaided flight
- Day flight
- Excessive-G flight

Susceptible at **ANYTIME** in flight

Spatial Orientation or Disorientation

Focal Vision

Ambient Vision

Vestibular

Proprioceptive

Interpretation of Cues

Oriented Flight

Type I SD

Control Based on
False Precept

Inappropriate Control
or
Loss Control

Aircraft Accident

Error Recognition

Disorientation Stress

Degraded Performance

Type II SD

Motor System
Response

Conflict Resolution

Correct Control
Of Aircraft

Safe Flight

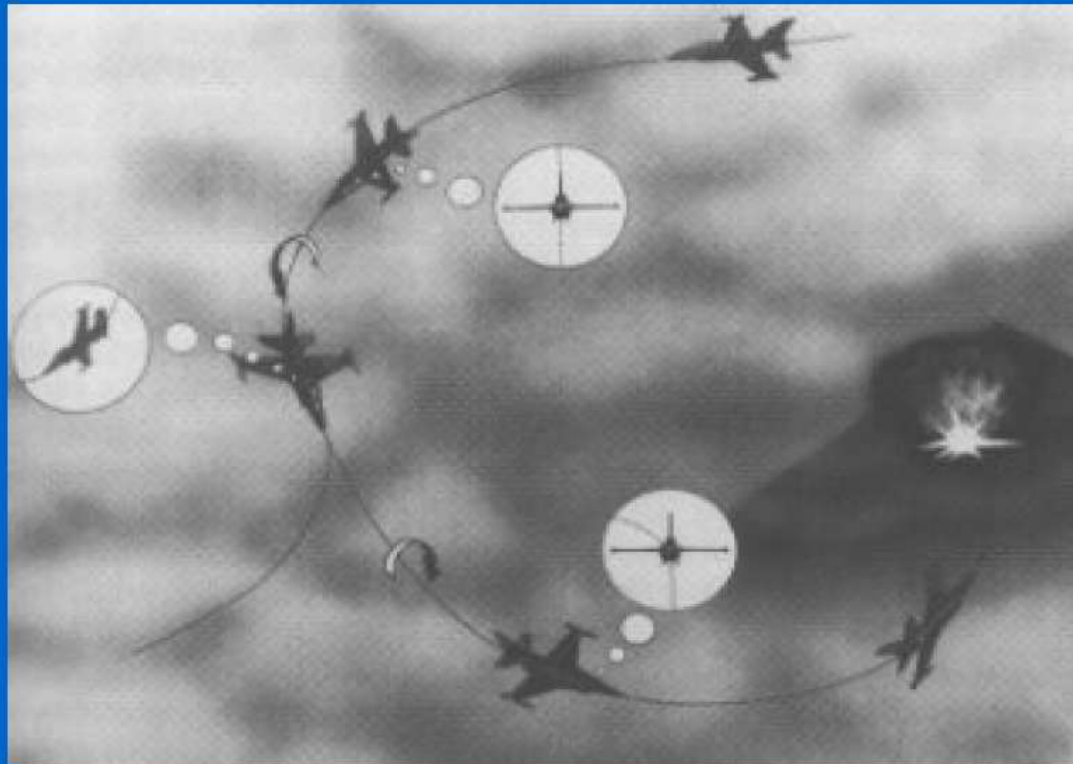
Graveyard Spiral

Type I (Unrecognized)

A factor when a person's cognitive awareness of one or more of the following varies from reality:

- Attitude
- Position
- Velocity
- Direction of motion
- Acceleration

Proper control inputs are not made because the need is unknown.

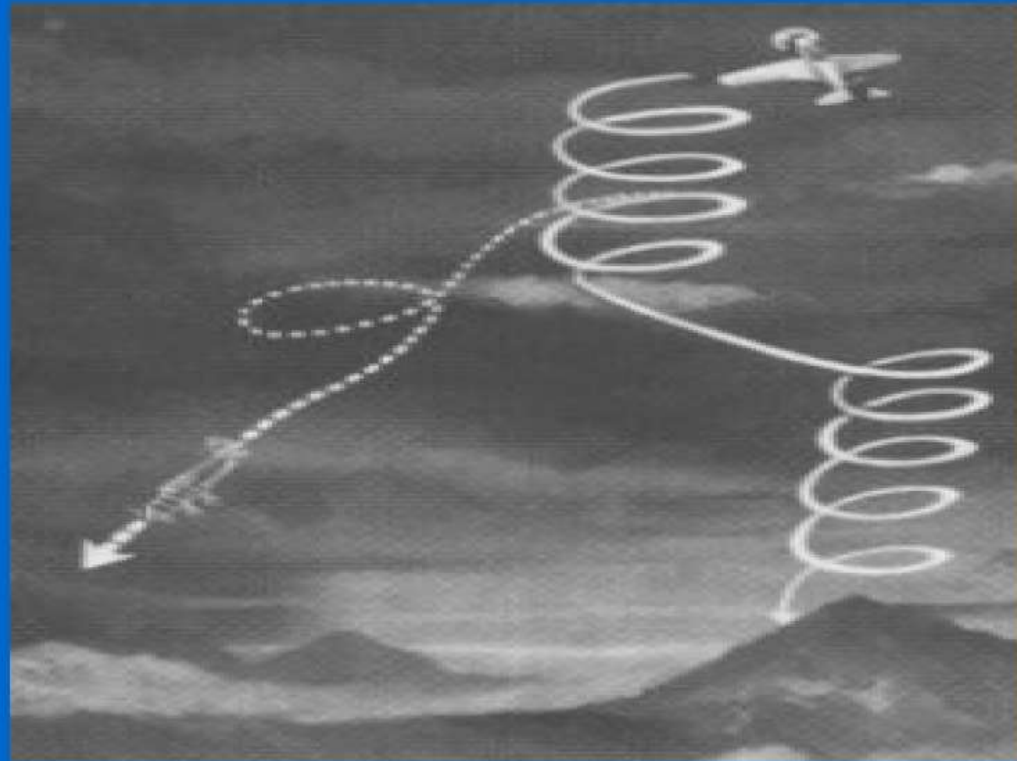


Somatogyral Illusion

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Graveyard Spin

Type I (Unrecognized)



Somatogyral Illusion

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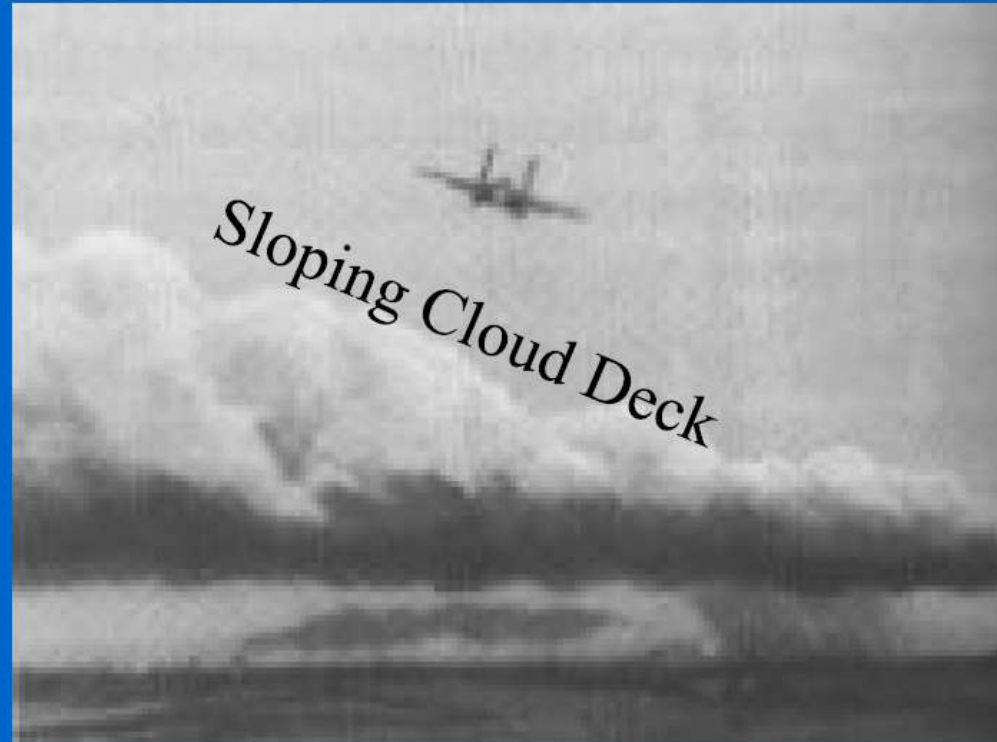
Leans

Type II (Recognized)

– A factor when recognized perceptual confusion is induced through one or more of the following senses:

- Visual
- Vestibular
- Auditory
- Tactile
- Proprioception
- Kinesthetic

Proper control inputs are still possible.



Somatogyral Illusion

Spatial Disorientation Type III

Incapacitating SD/ Type III

Disorientation Stress

Unable to apply
Motor System
Response

Degraded Performance

Egress

Aircraft Accident

Possible Effectors:

Giant Hand Phenomena
Coriolis Effect
Pressure Vertigo
Vertigo Flicker

Giant Hand Phenomenon

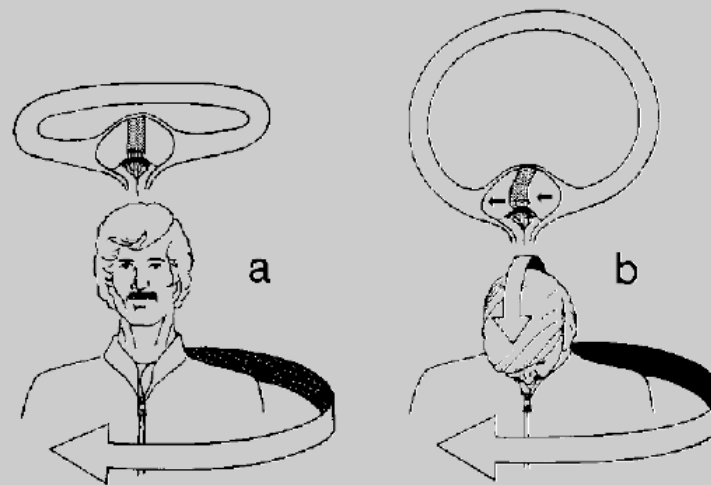
Type III (Incapacitating)



–Type III (Incapacitating): A factor when an individual is unable to make proper control inputs for safe operation of the aircraft or system due to a conflict (often extreme) between the sensory systems identified in Type II.

Type III (Incapacitating)

CORIOLIS ILLUSION



Somatogyral Illusion

Type III Incapacitating

Pressure Vertigo



Somatogyral Illusion

- A recognized condition where recovery is extremely difficult
- Senses provide incorrect/conflicting information
- Excessive eye movements (nystagmus)

"Flicker Vertigo"



Oculogyral Illusion

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Function of Otolith Organ

Linear Acceleration

**False sensation of pitch up
or down**

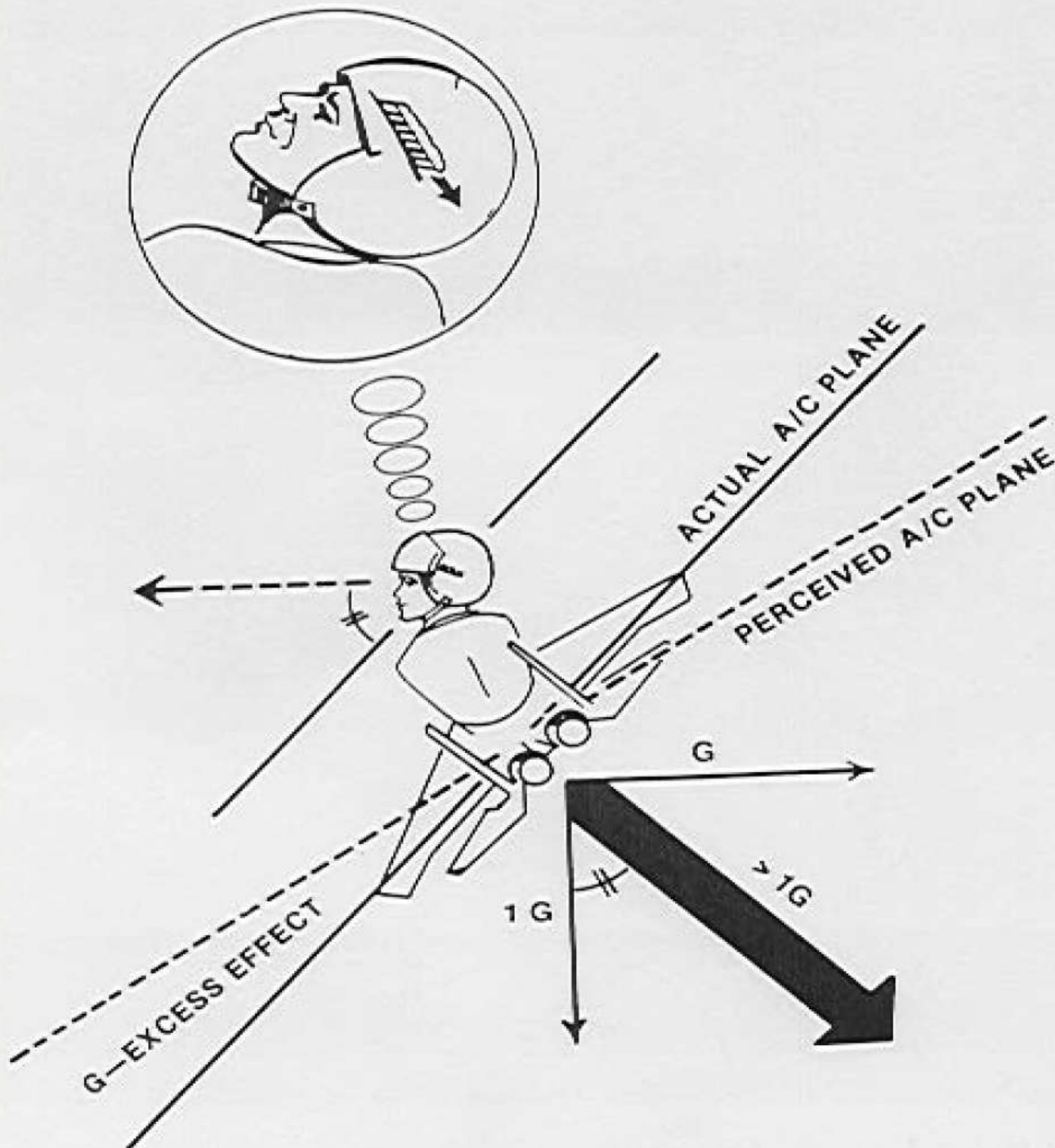
**Problems with acceleration
and deceleration**



Somatogravic Illusion

Oculogravic Illusion

G EXCESS ILLUSION



Somatogravic Illusion





Inversion Illusion

High acceleration with
push over to level
flight then accelerate

Somatogravic Illusion

Proprioceptive

Preventing Disorientation

- Maintain effective instrument scan
- Reduce task loading
- Compartmentalize
- Be familiar with geographical features



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Treatment and Correction

Transition to instruments
Believe the instruments
Make instruments read right
Minimize head movements
Fly straight and level
Reduce Task Loading
Transfer Control if Possible
Be familiar with geographical features
COMMUNICATION



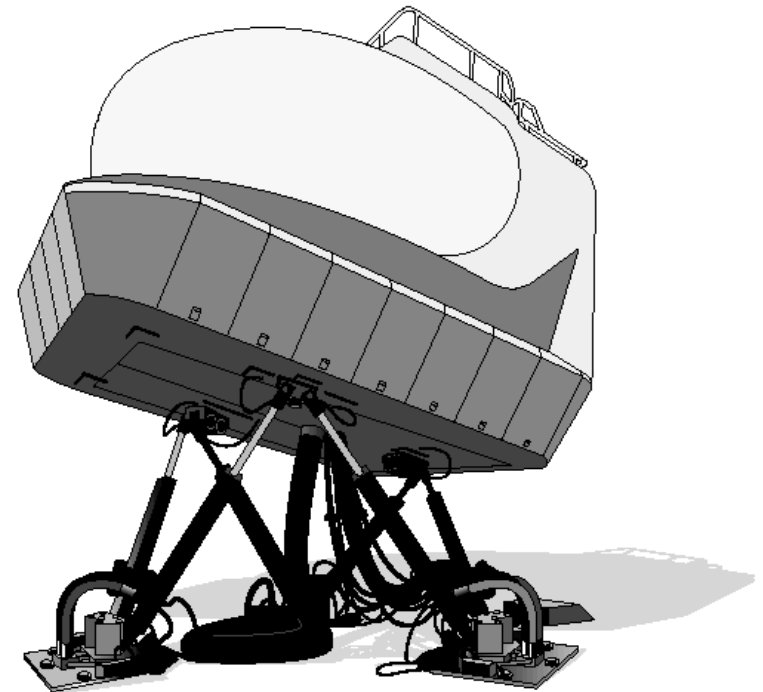
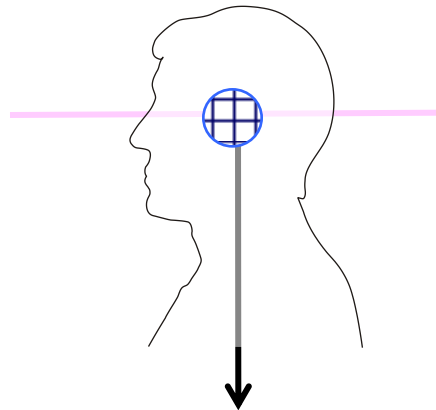


Simulators cannot mimic all illusions



- Flying in the simulator can provoke 'some' of these illusions, but the accelerated 'g' never exceeds 1g. Thus simulators cannot mimic the false climb illusion (false 'nose up' sensation due to acceleration or nose down due to deceleration).

Simulators have tilt but no acceleration.



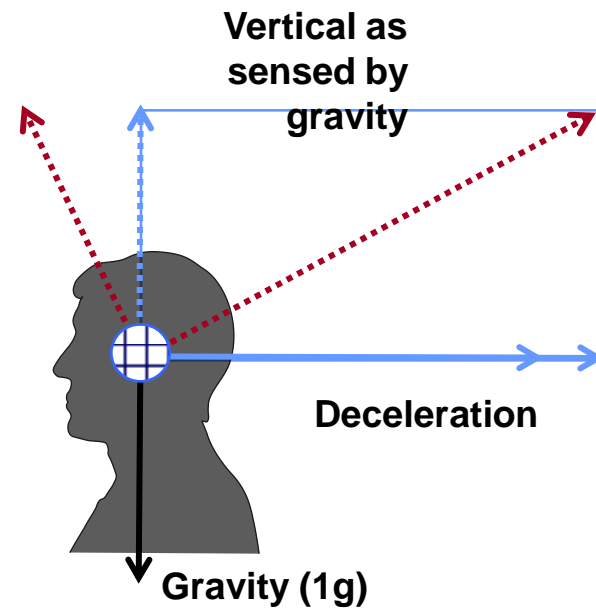


False 'attitude' illusion on approach



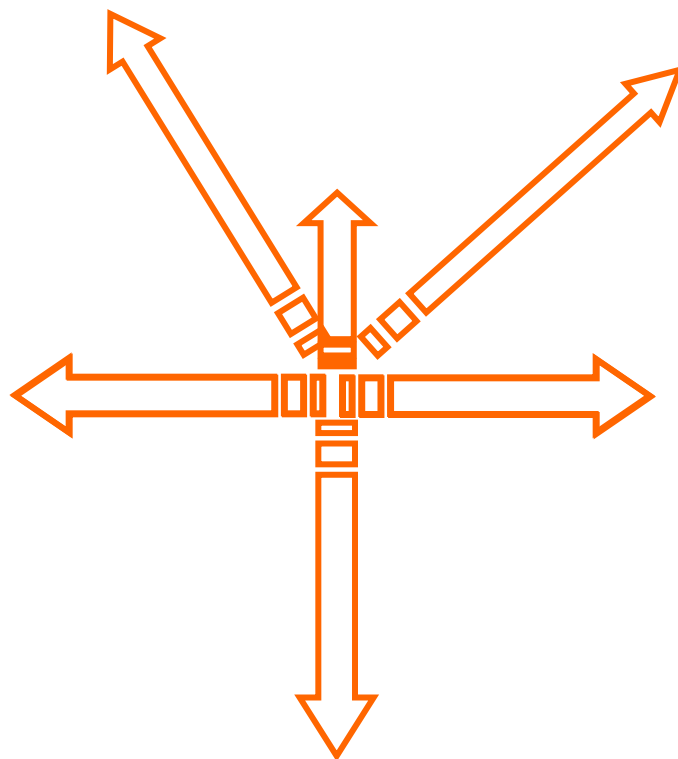
- Deceleration due to lowering the flaps/use of airbrake is perceived as a nose down sensation
- On the runway, before the nose wheel touches down, the deceleration from spoilers may be perceived falsely as a too-low pitch attitude.

False vertical due to deceleration; gives apparent nose down pitch





Scan your flight instruments



**Scan all instruments and believe their readings.
Do not make control inputs based on your
'feelings.'**

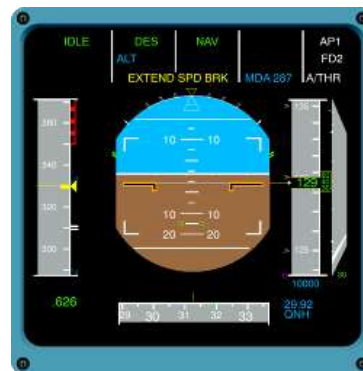


Recovery from Spatial Disorientation



Recover from disorientation by scanning the instruments:

- Use the instrument reading, regardless of your sensation.
- Don't trust your equilibrium organs, particularly in low-visibility conditions.
- In moments of stress, make decisions based on the instruments, and don't use your 'instinct,' i.e. perception.





Preventing Spatial Disorientation



- Having confidence, competence and currency in instrument flying reduces the risk of disorientation
 - Use an instrument scan - practice
- Prioritize the workload
 - First fly the aircraft, then consider other things
- Build up experience in controlling the aircraft in an environment of conflicting orientation cues
 - Practice go-arounds in the aircraft
- Avoid disorientation by making frequent instrument cross-checks, even when the autopilot is engaged

Understand Spatial Disorientation



SPEED ALT CRZ NAV AP



Scan your flight instruments





Questions?

