Air Force Aero Clubs,

The focus the past couple of months has been on topics that promote a safety minded culture and occurrences that can commonly affect pilot’s ability to operate safely while flying. This month I want to also recognize that protecting pilot’s health and wellbeing is also an important part of the Aero Club safety culture that should be promoted.

Hearing loss for pilots is a common occurrence because of the frequent and sustained exposure to decibels (dB) above safe levels. The range of noise intensity for many of the general aviation aircraft Aero Clubs fly is in the range of 100-110 dB. Jet aircraft which members can also be exposed to frequently due to proximity to Air Force jet aircraft can be 110+ dB depending on proximity. The OSHA established noise exposure limit at 105 dB is 1 hour of exposure. Pilots flying in club aircraft can easily be exposed to noise levels for this amount of time and beyond and why it is important to educate utilizing proper hearing protection. There are many different options available to pilots for ear protection like ear plugs, which can reduce noise levels approximately 30 dB, or various type of communication headsets that can be worn while flying.

Attached is a very informative article on hearing loss in aviation and protection options available. Also attached is a FAA Pilot Safety Brochure on Hearing and noise in aviation.

Fly Safely,

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A 2008 study by hearing expert Sergei Kochkin found that 35 million Americans have permanent hearing impairment. Based on current trends, that number is expected to grow to 40 million by 2025, representing nearly 12% of the U.S. population. While statistics on hearing loss among pilots aren’t easy to compile (because most pilots try to hide their hearing problems), both the FAA and the U.S. Military have launched their own studies, and the results are both surprising and disturbing: Permanent hearing loss occurs in about 30% of aviators. As a professional musician for many years, hearing is a keen interest of mine, and the effects of long-term exposure to harmful sound is something I’ve examined carefully, especially because I also fly.

Some form of hearing impairment is almost universal among pilots, and is especially evident in those who began flying before the advent of headsets. The subject is serious enough that even NASA has embarked on studies that examine hearing damage among pilots and ways to prevent it. And the issue of pilots flying with impaired hearing is something the Flight Safety Foundation—an independent international group—has focused on in terms of the risk of aviation accidents.

It’s true that some hearing loss is a by-product of aging. But several formal studies—including one conducted by the British Defense Research Agency and another by the U.S. Army—found that aging doesn’t account solely for the increased hearing loss among aviators. In comparison to nonaviators, pilots were found to have a greater decrease in hearing ability in the high-frequency range of 2–6 kHz. While the entire spectrum of the human voice covers from 250 Hz to 3 kHz, sounds like warning announcements and subtle changes in engine sounds or airflow can be missed due to high-frequency hearing loss, and ATC communications become difficult to discern.
How Loud Can Aviation Be?

Our sense of hearing is quite complex, while the mechanics of sound are relatively simple. In essence, sound starts out as a wave of pressure that emanates from the center of a source and radiates outward, like the waves formed when a pebble is tossed into a still pond. The “pressure” is made of air molecules; the louder the sound, the more sound pressure is generated. This pressure—in the form of air—acts upon our eardrum. We perceive a shout as being louder than a whisper because more air molecules strike our eardrum from a shout than a whisper. This pressure is measured in units called “decibels,” noted by the abbreviation “dB.”

Sounds (pressure waves) are “collected” and directed by the outer ear toward the ear canal and cochlea (named for its resemblance to a snail shell). The waves of air pressure move tiny hair-like cells inside the cochlea—much the same way as a gentle breeze blows across a field full of long grass. Those hairs transmit signals to the brain via the auditory nerve. Hearing damage occurs when the sound is loud enough to break the fragile hair-like cells in the cochlea. The length of time we’re exposed to sound and the frequency of the sound determine the extent of damage. Once those tiny cells are broken, there’s no repair.

To give some sense to all this, it’s helpful to know that a human whisper measures about 30 dB, while a normal conversation happens at around 60 dB. A jackhammer pounds the concrete at some 120 dB, and you tool along in your car on the highway at 70 dB. Physical pain begins at about 125 dB, and your eardrum will burst with exposure to 140 dB.

The Occupational Safety and Health Organization (OSHA) has established that the maximum level of “safe” exposure to loud sounds is 90 dB for up to eight hours, or 100 dB for up to two hours. Meanwhile, the Environmental Protection Agency (EPA) has established their own exposure-level standards that are more conservative, with a maximum of 85 dB for up to eight hours and 92 dB for one hour. How does general aviation measure in comparison?
NASA conducted experiments by placing microphones inside a Cessna 182 to measure sound during different phases of flight (run-up, cruise, climb, etc.). NASA found maximum sound levels of between 105 and 109 dB. Another more recent study by OSHA measured noise levels in a Cessna 172S and found an average maximum sound level of just over 101 dB. The main thing to remember here is that any noise over 90 dB means hearing loss unless you wear ear protection. In both studies, the only factor that reduced noise consistently was wearing a headset.

ANR Versus PNR
By now, most pilots understand the difference between passive headsets (PNR—Passive Noise Reduction) and active headsets (ANR—Active Noise Reduction). Aside from the price (active is more expensive), both types offer good hearing protection, though they go about it differently and are for different environments. It's important to understand the differences.

ANR headsets work by sampling the damaging noise coming into the ear cup with a miniature microphone and then “canceling” that noise by generating a counter-noise through a tiny speaker, also inside the ear cup. The effect is like hitting a pool of water with your hand. The left hand can be the “bad” noise. When you strike your fist onto the water, waves radiate from it. Then, thinking of your right fist as the “good” noise, pounding it on the water with the same force creates another set of waves. As the two waves meet they cancel each other out and dissipate, just like sound. ANR proponents say it's the best solution for protecting your hearing.

Mostly, ANR attenuates frequencies in the lower spectrum, from about 20 Hz to around 300 Hz, with peak reduction at 70–150 Hz. Studies have shown that peak noise levels generated by the propeller, engine and exhaust all combine around the 100 Hz point—precisely the area that ANR attenuates best. Higher-frequency noise is caused mostly by air flowing over the cockpit and fuselage. Most ANR headsets don't attenuate high frequencies. Because each airplane's noise signature is different, a headset that's right for one aircraft owner isn't necessarily right for another.

Headset manufacturers aren't keen on showing you their frequency response charts. They figure most consumers don't understand them, so they just give an overall attenuation rating of, say, 40 dB. The key is finding out which harmful sound frequency the headset attacks at that rating. For example, the “40 dB” claim may reduce only 100 Hz by that much, while 2000 Hz (in the human voice spectrum) isn't attenuated at all and is more harmful. Consumers should examine the breadth of the attenuation (span of
Passive headsets block noise by physically stopping it. PNR sets clamp tightly to your head, preventing sound-pressure waves from reaching your ears. Insulation and different materials block sound waves or dissipate them. There’s no magic to PNR; using the fist-in-the-water analogy again, the waves you made with your left hand would simply be blocked by a dam—the PNR headset being that dam. One advantage of PNR sets is they’re great at blocking frequencies in the 1000-Hz-and-up range. They do it using clamping pressure and ear-cup design. That makes them less comfortable than ANR sets, but more effective in scenarios where your enemy is high frequency (like in an open-cockpit aircraft).

Ear Cups
Believe it or not, ear cups—the round things on headsets that go over your ears—make a big difference. In recent years, different materials have been found to be especially effective at blocking unwanted cockpit noise. Some manufacturers are using materials like magnesium, or modifying the ear-cup shape to enhance attenuation and performance. Related to the ear cup is the clamping pressure. While ANR headsets clamp lightly (they rely on the circuitry to reduce noise), PNR sets depend on clamping for noise reduction. So try on a headset for an extended period of time so you can detect any clamping pressure hotspots on your ears or head. Any headset worn in the store for 20 seconds feels good.

Ear Seals
Ear seals (the soft rings that attach to the headset’s ear cups) have been getting a lot of attention lately. Oregon Aero has been offering retrofit kits for various headsets for some time now, and pilots are beginning to appreciate the comfort and noise reduction available from good ear seals. The best ones are breathable to reduce sweat. That means organic materials like cotton and leather work best. Also, thick ear seals that elevate the ear cup away from your ear have been found to increase comfort on long flights.

Microphones
Headset microphones come in two basic flavors: dynamic and electret condenser. In recent years, more manufacturers have switched to electret-condenser microphones for general aviation headsets. An electret-condenser mic generates a powered signal that sounds louder and clearer and with less background noise. Dynamic microphones are nonpowered and still used on older—and especially military—aircraft. They cost less and handle abuse better, but are becoming nonstandard in today’s GA environment. As a general rule, use the same type of headset microphones in all your intercom outlets.

The Latest Thing
Just recently, pilots in noisy environments have discovered what musicians have known for some time: Doubling up on hearing protection is great insurance against hearing loss. That means using multiple forms of noise attenuation that won’t color the sound you’re accustomed to hearing. Several companies make special ear plugs that have a tiny removable sound filter that reduces noise in certain frequencies. Next time, instead of shoving those cheap foam plugs into your ears that block everything and make you
feel like you have a monster head cold, use custom plugs. Since they only block harmful frequencies, normal sounds come through loud and clear. Using these custom plugs in addition to your regular headset adds 15 to 20 dB of additional noise reduction. Ask your audiologist for frequency-specific ear plugs or “musician’s ear plugs.” They normally run under $100, including the molds.

The most important fact from all of this is that headsets are a vital part of any pilot’s equipment. Among aviators, hearing loss seems to be a given. Caused by early neglect, improper headsets or infrequent use of them, it’s a loss that doesn’t have to exist. Hearing is a valuable sense considered second only to sight, and especially so for pilots. It makes sense to protect it at any cost. Don’t take hearing loss lightly and don’t think, “It won’t happen to me,” because if you fly long enough, it will.

Headset Highlights

New models, thoughtful enhancements and greater comfort are the hallmarks of this year’s newest headset products.

We take the era we live in for granted. When it comes to headsets, the industry has made advances in recent years that surpass the developments of the previous 100 years combined. For example, ANR was only brought to GA in the mid-1980s. Bluetooth wireless technology didn’t come into its own until the last few years. Advanced materials like composites have only been popular in the recent decade, and the tiny, efficient speaker drivers that make your iPod sound great and allow your home sound system to fit into a shoebox have only been around a short time.

With aviation headsets, we fully expect that whatever model we bought last year will probably be surpassed by a new model this year, with more and better features. While veteran pilots trudged along with their “Realistic-” brand microphone for three decades, we expect to upgrade our headsets every few years. It’s an exciting time in aviation, and the most recent announcements in the headset world are worth taking a look at. What follows is the latest and greatest in aviation headsets.

BeyerDynamic HS600 DAB

BeyerDynamic HS600 DAB
Long a force in the music and broadcast world, German company Beyerdynamic continues to offer their outstanding “Digital Adaptive” Noise Reduction (DAB) system in aviation headsets. Their innovative approach tailors the active noise reduction to specific frequencies based on the frequencies sensed by the ear-cup sensor. The result is excellent attenuation that’s adaptable to different environments. Add connections to
HEARING AND NOISE IN AVIATION

HEARING

The term hearing describes the process, function, or power of perceiving sound. Hearing is second only to vision as a physiological sensory mechanism to obtain critical information during the operation of an aircraft. The sense of hearing makes it possible to perceive, process, and identify among the myriad of sounds from the surrounding environment.

Anatomy and Physiology of the Auditory System

The auditory system consists of the external ear, ear canal, eardrum, auditory ossicles, cochlea (which resembles a snail shell and is filled with fluid), and the auditory nerve.

Ambient sound waves are collected by the external ear, conducted through the ear canal, and cause the eardrum to vibrate. Eardrum vibration is mechanically transmitted to the ossicles, which, in turn, produce vibration of a flexible window in the cochlea. This vibration causes a pressure wave in the fluid located inside the cochlea, moving thousands of hair-like sensory receptors lining the inner walls of the cochlea. The movement of these receptors resembles the gentle movement of a crop field caused by the wind. The stimulation of these sensors produces an electrical signal that is transmitted to the brain by the auditory nerve. This signal is then processed by the brain and identified as a particular type of sound.

SOUND

The term sound is used to describe the mechanical radiant energy that is transmitted by longitudinal pressure waves in a medium (solid, liquid, or gas). Sound waves are variations in air pressures above and below the ambient pressure. From a more practical point of view, this term describes the sensation perceived by the sense of hearing. All sounds have three distinctive variables: frequency, intensity, and duration.

Frequency. This is the physical property of sound that gives it a pitch. Since sound energy propagates in a wave-form, it can be measured in terms of wave oscillations or wave cycles per second, known as hertz (Hz). Sounds that are audible to the human ear fall in the frequency range of about 20-20,000 Hz, and the highest sensitivity is between 500 and 4,000 Hz. Sounds below 20 Hz and above 20,000 Hz cannot be perceived by the human ear. Normal conversation takes place in the frequency range from 500 to 3,000 Hz.

Intensity. The correlation between sound intensity and loudness. The decibel (dB) is the unit used to measure sound intensity. The range of normal hearing sensitivity of the human ear is between -10 to +25 dB. Sounds below -10dB are generally imperceptible. A pilot who cannot hear a sound unless its intensity is higher than 25 dB (at any frequency) is already experiencing hearing loss.

Duration. Determines the quality of the perception and discrimination of a sound, as well as the potential risk of hearing impairment when exposed to high intensity sounds. The adverse consequences of a short-duration exposure to a loud sound can be as bad as a long-duration exposure to a less intense sound. Therefore, the potential for causing hearing damage is determined not only by the duration of a sound but also by its intensity.

NOISE

The term noise refers to a sound, especially one which lacks agreeable musical quality, is noticeably unpleasant, or is too loud. In other words, noise is
any unwanted or annoying sound. Categorizing a sound as noise can be very subjective. For example, loud rock music can be described as an enjoyable sound by some (usually teenagers), and at the same time described as noise by others (usually adults).

**Sources of Noise in Aviation.** The aviation environment is characterized by multiple sources of noise, both on the ground and in the air. Exposure of pilots to noise became an issue following the introduction of the first powered aircraft by the Wright Brothers, and has been a prevalent problem ever since. Noise is produced by aircraft equipment powerplants, transmission systems, jet efflux, propellers, rotors, hydraulic and electrical actuators, cabin conditioning and pressurization systems, cockpit advisory and alert systems, communications equipment, etc. Noise can also be caused by the aerodynamic interaction between ambient air (boundary layer) and the surface of the aircraft fuselage, wings, control surfaces, and landing gear. These auditory inputs allow pilots to assess and monitor the operational status of their aircraft. All pilots know the sounds of a normal-functioning aircraft. On the other hand, unexpected sounds or the lack of them, may alert pilots to possible malfunctions, failures, or hazards. Every pilot has experienced a cockpit or cabin environment that was so loud that it was necessary to shout to be heard. These sounds not only make the work environment more stressful but can, over time, cause permanent hearing impairment. However, it is also important to remember that individual exposure to noise is a common occurrence away from the aviation working environment—at home or work, on the road, and in public areas. The effects of pre-flight exposure to noise can adversely affect pilot in-flight performance.

**Types of Noise**

**Steady:** Continuous noise of sudden or gradual onset and long duration (more than 1 second). Examples: aircraft powerplant noise, propeller noise, and pressurization system noise. According to the Occupational Safety and Health Administration (OSHA), the maximum permissible continuous exposure level to steady noise in a working environment is 90 dB for 8 hours.

**Impulse/blast:** Noise pulses of sudden onset and brief duration (less than 1 second) that usually exceed an intensity of 140dB. Examples: firing a handgun, detonating a firecracker, backfiring of a piston engine, high-volume squelching of radio equipment, and a sonic boom caused by breaking the sound barrier. The eardrum may be ruptured by intense levels (140dB) of impulse/blast noise.

**EFFECTS OF NOISE EXPOSURE**

**Physiologic**

- **Ear discomfort:** May occur during exposure to a 120 dB noise.
- **Ear pain:** May occur during exposure to a 130 dB noise.
- **Eardrum rupture:** May occur during exposure to a 140 dB) noise.
- **Temporary hearing impairment.** Unprotected exposure to loud, steady noise over 90 dB for a short time, even several hours, may cause hearing impairment. This effect is usually temporary and hearing returns to normal within several hours following cessation of the noise exposure.
- **Permanent hearing impairment:** Unprotected exposure to loud noise (higher than 90dB) for eight or more hours per day for several years, may cause a permanent hearing loss. Permanent hearing impairment occurs initially in the vicinity of 4,000 Hz (outside the conversational range) and can go unnoticed by the individual for some time. It is also important to remember that hearing sensitivity normally decreases as a function of age at frequencies from 1,000 to 6,000 Hz, beginning around age 30.

**Sources of Sound/Noise**

<table>
<thead>
<tr>
<th>SOURCES</th>
<th>LEVEL (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whispered Voice</td>
<td>20-30</td>
</tr>
<tr>
<td>Urban Home, Average Office</td>
<td>40-60</td>
</tr>
<tr>
<td>Average Male Conversation</td>
<td>60-65</td>
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<tr>
<td>Noisy Office, Low Traffic Street</td>
<td>60-80</td>
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<tr>
<td>Jet Transports (Cabin)</td>
<td>60-88</td>
</tr>
<tr>
<td>Small Single Plane (Cockpit)</td>
<td>70-90</td>
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<tr>
<td>Public Address (PA) Systems</td>
<td>90-100</td>
</tr>
<tr>
<td>Busy City Street</td>
<td>80-100</td>
</tr>
<tr>
<td>Single Rotor Helicopter (Cockpit)</td>
<td>80-102</td>
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<tr>
<td>Power Lawn Mower, Chain Saw</td>
<td>100-110</td>
</tr>
<tr>
<td>Snowmobile, Thunder</td>
<td>110-120</td>
</tr>
<tr>
<td>Rock Concert</td>
<td>115-120</td>
</tr>
<tr>
<td>Jet Engine (Proximity)</td>
<td>130-160</td>
</tr>
</tbody>
</table>
Psychologic

- **Subjective effects**: Annoying high-intensity noise can cause distraction, fatigue, irritability, startle responses, sudden awakening and poor sleep quality, loss of appetite, headache, vertigo, nausea, and impair concentration and memory.

- **Speech interference**: Loud noise can interfere with or mask normal speech, making it difficult to understand.

- **Performance**: Noise is a distraction and can increase the number of errors in any given task. Tasks that require vigilance, concentration, calculations, and making judgments about time can be adversely affected by exposure to loud noise higher than 90 dB.

### HOW TO PROTECT YOUR HEARING

**Limiting duration of exposure to noise.** OSHA-established permissible noise exposure limits for the workplace (including the cockpit of an aircraft):

<table>
<thead>
<tr>
<th>Noise Intensity (dB)</th>
<th>Exposure Limit (hrs. per day)</th>
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<tbody>
<tr>
<td>90</td>
<td>8</td>
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<tr>
<td>92</td>
<td>6</td>
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<td>95</td>
<td>4</td>
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<td>97</td>
<td>3</td>
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<td>100</td>
<td>2</td>
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<tr>
<td>102</td>
<td>1.5</td>
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<tr>
<td>105</td>
<td>1</td>
</tr>
<tr>
<td>110</td>
<td>.5</td>
</tr>
<tr>
<td>115</td>
<td>.25</td>
</tr>
</tbody>
</table>

**Use Hearing Protection Equipment.** If the ambient noise level exceeds OSHA’s permissible noise exposure limits, you should use hearing protection devices—earplugs, earmuffs, communication headsets, or active noise reduction headsets. Even if an individual already has some level of permanent hearing loss, using hearing protection equipment should prevent further hearing damage. These protection devices attenuate noise waves before they reach the eardrum, and most of them are effective at reducing high-frequency noise levels above 1,000 Hz. It is very important to emphasize that the use of these devices does not interfere with speech communications during flight because they reduce high-frequency background noise, making speech signals clearer and more comprehensible.

- **Earplugs.** Insertable-type earplugs offer a very popular, inexpensive, effective, and comfortable approach to provide hearing protection. To be effective, earplugs must be inserted properly to create an air-tight seal in the ear canal. The wax-impregnated moldable polyurethane earplugs provide an effective universal fit for all users and provide 30 to 35 dB of noise protection across all frequency bands.

- **Communication headsets.** In general, headsets provide the same level of noise attenuation as earmuffs, and are also more easily donned and removed that earplugs, but the microphone can interfere with the donning of an oxygen mask.

- **Active noise reduction headsets.** This type of headset uses active noise reduction technology that allows the manipulation of sound and signal waves to reduce noise, improve signal-to-noise ratios, and enhance sound quality. Active noise reduction provides effective protection against low-frequency noise. The electronic coupling of a low-frequency noise wave with its exact mirror image cancels this noise.

- **Combinations of protection devices.** The combination of earplugs with earmuffs or communication headsets is recommended when ambient noise levels are above 115dB. Earplugs, combined with active noise reduction headsets, provide the maximum level of individual hearing protection that can be achieved with current technology.

### SUMMARY

- Hearing is second only to vision as a sensory mechanism to obtain critical information during the operation of an aircraft.

- All sounds have three distinctive variables: frequency, intensity, and duration.

- Normal conversation takes place in the frequency range from 500 to 3,000 Hz.

- Daily exposure to noise levels higher than 90dB can cause hearing impairment. This can go unnoticed initially because it occurs in the vicinity of 4,000 Hz (outside the conversational range)

- If the ambient noise level reaches 90dBA, you
must use hearing protection equipment to prevent hearing impairment.

- Exposure to loud noise before flying (at home, while driving, at a party, etc.) can be as harmful as exposure to aircraft noise.

**MEDICAL FACTS FOR PILOTS**

*Publication: AM-400-98/3*

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*Prepared by: FAA Civil Aerospace Medical Institute*

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*Oklahoma City, OK 73125*

**Other Pilot Safety Brochures Available**

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
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<tbody>
<tr>
<td>AM-400-94/2</td>
<td>Alcohol and Flying: A Deadly Combination</td>
</tr>
<tr>
<td>OK05-0270</td>
<td>Carbon Monoxide: A Deadly Threat</td>
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<tr>
<td>AM-400-03/2</td>
<td>Deep Vein Thrombosis and Travel</td>
</tr>
<tr>
<td>AM-400-91/1</td>
<td>Hypoxia: The Higher You Fly, the Less Air...</td>
</tr>
<tr>
<td>AM-400-97/1</td>
<td>Introduction to Human Factors in Aviation</td>
</tr>
<tr>
<td>AM-400-92/1</td>
<td>Over the Counter Medications and Flying</td>
</tr>
<tr>
<td>AM-400-98/2</td>
<td>Pilot Vision</td>
</tr>
<tr>
<td>AM-400-95/1</td>
<td>Smoke!</td>
</tr>
<tr>
<td>AM-400-00/1</td>
<td>Spatial Disorientation: Visual Illusions</td>
</tr>
<tr>
<td>AM-400-03/1</td>
<td>Spatial Disorientation: Why You Shouldn’t Fly By the Seat of Your Pants</td>
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<tr>
<td>AM-400-01/1</td>
<td>Physiological Training Courses for Civil Aviation Pilots</td>
</tr>
<tr>
<td>AM-400-05/1</td>
<td>Sunglasses for Pilots: Beyond the Image</td>
</tr>
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</table>

To view these pilot and passenger safety brochures, visit the Federal Aviation Administration's Web Site:

[www.faa.gov/pilots/safety](http://www.faa.gov/pilots/safety)

**Physiological Training Classes for Pilots**

If you are interested in taking a one-day aviation physiological training course with altitude chamber and vertigo demonstrations or a one-day survival course, learn about these courses by visiting this FAA Web site:

[www.faa.gov/pilots/training/airman_education](http://www.faa.gov/pilots/training/airman_education)