The National Council on Radiation Protection and Measurements reports that among those U.S. workers exposed to radiation while on the job, flight crews get the largest annual effective dose. That’s not a good thing.

Ultraviolet (UV) radiation is invisible to the human eye but can burn the skin and cause skin cancer including melanoma as well as damage to one’s eyes. The chronic effects of UV exposure can be serious, even life threatening, and include premature aging of the skin, suppression of the immune system, along with eye damage and skin cancer.

These invisible rays are part of solar energy. UV radiation comprises three types, commonly referred to as UVA, UVB and UVC. (The difference is due to different wavelengths. UVC wavelengths are in the range of 100 to 280 nanometers, UVB wavelengths range from 280 to 315 nanometers and UVA wavelengths are in the range of 315 to 400 nanometers.)

Fortunately, the ozone layer that resides in a region of the stratosphere (50,000-165,000 ft. above sea level) is UV-absorbing and protects ground-dwellers from UVC and some of the UVB. UVA and some UVB do penetrate the ozone layer. UVA is weaker than UVB but penetrates deeper into the skin. It should be noted that, in general, there is a great deal of variability in UV radiation due to the sun’s angle of incidence, clouds, aerosols and other atmospheric constituents, as well as geographic location and altitude.

Accordingly, flight crews of high-performance aircraft are exposed to elevated levels of UV radiation as a result of their operations in the upper reaches of the troposphere and lower stratosphere. The air density in that portion of the earth’s atmosphere is thinner than at sea level and therefore filters less of the dangerous
solar radiation. UV radiation increases at about 6-10% with every 1,000 ft. of altitude. Between 31,000 and 41,000 ft., where most jet aircraft cruise, UV radiation exposure doubles. Additionally, according to “The Scientific Assessment Panel of the Montreal Protocol on Substances that Deplete the Ozone Layer” (UNEP/WMO Scientific Assessment of Ozone Depletion, July 2002) the destruction of stratospheric ozone (by chlorofluorocarbons and other pollutants) may increase UV radiation exposure. This is especially true close to the equator and both poles due to the thinning of the ozone layer in these regions.

Ralf Meerkotter, director of the German Aerospace Center’s Institute of Atmospheric Physics, found that occupational UV radiation exposure for pilots depends on numerous factors, including the entire time a pilot spent in a cockpit, the number of flights along specific routes, the specific windscreen properties of the aircraft, the individual skin type of a pilot, sun position during flight from takeoff to landing, and the day of the year.

According to Meerkotter, the most impactful of such factors is the most obvious: the incidence angle of the sun with the aircraft’s windscreen. The intensity of UV radiation inside the cockpit strongly depends on whether direct sun is entering or not. Without direct sun, the diffuse UV radiation inside the cockpit amounts to about 5% of the ambient UV irradiance outside the aircraft. In cases of low sun when direct radiation can reach the pilot, percentages grow from 50 to 100%.

The amount of UV radiation absorbed by aircraft windscreens depends on the constructional material used and the general design. In a study released in 2007, the transmittance properties of aircraft windscreens were measured at the FAA’s Civil Aerospace Medical Institute (CAMI) for both visible and invisible optical radiation. Transmission measurements were performed on eight aircraft windscreens. Three windscreens were from large commercial jets (MD-88, Airbus A320 and Boeing 727/737); two from commercial, propeller-driven passenger planes (Fokker 27 and ATR 42); one from a small private jet (Raytheon Hawker Horizon); and two from small general aviation, single-engine, propeller-driven planes (Beech Bonanza and Cessna 182).

The general aviation aircraft windscreens were plastic (polycarbonate); the others were multilayer (laminated) composite glass. UV transmittance for both glass and plastic windscreens was less than 1% for UVB (280-320 nanometer) radiation. In the UVA portion of the spectrum, transmittance differences increased from 0.41% to 53.5%, with plastic attenuating (i.e., lessening) more UV radiation than glass.

“These results suggest that plastic windscreens outperform glass by protecting the pilot’s eyes from UV radiation,” according to the study, “Optical Radiation Transmittance of Aircraft Windscreens and Pilot Vision.” And it noted that, “Professional pilots who routinely fly at higher altitude for longer periods of time than private pilots should take special precautions to protect their eyes from UV exposure.”

Meanwhile, Dr. Adrian Chorley of Britain’s Civil Aviation Authority and London South Bank University’s Department of Primary Care and Public Health, who conducts research in optometry and ophthalmology, studied ocular UV exposure of pilots in airline and offshore helicopter operations on different aircraft types. Inflight data were captured on five return-sector European airline flights and one transatlantic flight from London Gatwick Airport in addition to four helicopter flights from Aberdeen Dyce Airport.

The study found a wide variation in ocular UVA doses during flights. The main factor influencing exposure was the UV transmission of the windshield, which fell into two distinct profile types. In an aircraft with good UVA-blocking properties, ocular exposure was found to be equivalent to that of office exposure and did not exceed international guideline limits regardless of external conditions or flight time.
Most aircraft assessed had poor UVA-blocking windshields, which resulted in an ocular exposure to the unprotected eye in excess of international guideline limits. No significant UVB dose was found. A 2016 study, “Occupational Ocular UV Exposure in Civilian Aircrew,” recommended that pilots should be warned of the potential high UVA exposure during flight and advised on the use of sunglasses.

A research team led by Dr. Martina Sanlorenzo of the Department of Dermatology at the University of California San Francisco, measured UV radiation through the acrylic plastic windshield (1.6 cm thick) in front of the pilot seat of a TBM 850 at ground level, 2,500 ft., 6,000 ft., 10,000 ft., 15,000 ft., 20,000 ft., 25,000 ft. and 30,000 ft. around midnight during April at San Jose, California, and Las Vegas. Published in 2015, the study, “The Risk of Melanoma in Pilots and Cabin Crew: UV Measurements in Flying Airplanes,” determined that aircraft occupants flying for 57 min. at 30,000 ft. got the same amount of UVA radiation as from a 20-min. tanning bed session.

Sanlorenzo concluded, “Airplane windshields do not completely block UVA radiation and therefore not enough to protect pilots. UVA transmission inside airplanes can play a role in pilots’ increased risk of melanoma. . . . We believe that better UV protection on aircraft windshields is necessary to offer cabin crew a hazard-free work environment. We strongly recommend the use of sunscreens and periodical skin checks for pilots and cabin crew.”

In addition, Sanlorenzo led another team of medical researchers who reviewed more than 3,527 citations from 19 previous studies on melanoma published between 1990 and 2013, reported data from 1943 to 2008 from 11 countries, and included over 266,431 participants. The results of this study, “The Risk of Melanoma in Airline Pilots and Cabin Crew: A Meta-Analysis,” published in 2015, indicated that participants in flight-based occupations are twice as likely to contract melanoma than the general public. Furthermore, pilots specifically have a 42% higher mortality rate from melanoma compared with the general population. Researchers believe that the culprit is likely UV radiation, which can penetrate glass, even the specialty glass used in aircraft windshields.

Another significant hazard to pilots is the damage done to retinal photoreceptors caused by long-term exposure to solar UV radiation. Research was conducted by Chorley between 2008 and 2015 to study the matter. While he found no ill effects to the eyes caused by UVB and UVC since these types of UV radiation are filtered out by the upper atmosphere and the windshields of most aircraft, the study showed that UVA, the least energetic form of UV radiation, is the most harmful to a pilot’s eyes and eyesight because a higher percentage of it penetrates the cockpit and cabin of an aircraft.

Chorley reported that although rare, short, intense exposure to UVA may lead to conditions such as snow blindness and damage to the cornea. He notes in “Civilian Pilot Exposure to Ultraviolet and Blue Light and Pilot Use of Sunglasses,” that “there is good evidence that long-term exposure to solar radiation, especially the ultraviolet and blue light components, is a risk factor for cataracts and, to a lesser extent, age-related degeneration of the retina.”

There is a tool that a pilot can use to prevent this eyesight damage: sunglasses with sufficient UV protection. In an evaluation of 38 sunglasses used by commercial pilots, Chorley found that all conformed to international standards for UV radiation transmittance, offered sufficient UV radiation protection and against the increase in blue light exposure that pilots experience at altitude. However, used sunglasses with scratched lenses were less effective.

The study concluded that lenses manufactured to minimally comply with standards for UV radiation transmittance could result in excess UV radiation to a pilot based on inflight irradiance data. The study
recommended an additional requirement of less than 10% transmittance in the 380-nanometer wavelength.

An online survey conducted by Chorley of nearly 3,000 pilots in the UK regarding the use of sunglasses and other onboard protective devices to block sunlight revealed that pilots were critical of standard aircraft protection systems such as visors (and other commonly employed devices) to manage bright light. Sunglass use was found to be surprisingly variable. A quarter of those questioned wore sunglasses less than 10% of the time or not at all. The most common reasons for sunglasses not being used was the sunglass tint interfering with instrument legibility and discomfort from frames, particularly when used in conjunction with required headsets.

According to an FAA study, “Optical Radiation Transmittance of Aircraft Windscreens and Pilot Vision,” flying over a thick cloud layer or a snowfield with the Sun at its zenith increases the exposure to naturally occurring UV. Snow reflects 85% of visible and UV radiation, while clouds can reflect up to 80%. In such conditions, sunglasses with a closely fitting wraparound frame design are best since UV-blocking lenses are useless if radiation is allowed to enter the eye from the sides of the frame. A gray, neutral density filter to block 70-85% of all visible light is recommended to preserve color discrimination and enhance the ability to quickly adapt to lower light levels.

People often equate sunglasses with UV radiation protection. The FAA’s study pointed out that lens tints or color are not indicative of the UV blocking ability of a lens. While there are no UV radiation standards for clear prescription lens materials, the American Optometric Association recommends that sunglasses block at least 99% of solar UV radiation below 400 nanometers. Without UV treatments, clear glass and CR-39 lenses fall short of this mark. Therefore, it is important when purchasing non-prescription, over-the-counter sunglasses to be sure they are accompanied by proper labeling and/or documentation describing their UV protection properties.

Solar radiation is an invisible enemy that can cause long-lasting and potentially deadly consequences for pilots and crewmembers who are repeatedly exposed to higher levels of both UVA and UVB and for longer periods than those working on the ground. Pilots, especially those operating high-performance aircraft at high altitudes, need to protect themselves. The aviation industry as a whole needs to do a better job of protecting its most valuable assets, its people. BCA