Protection Against the Threat of Laser Beams

Operational and Training Procedures of the Brazilian Air Force

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Introduction

This article advocates the study of specialized protection against the threat of laser beams posed by subnational forces or ordinary citizens. Laser beam emissions against aircraft constitute a new strategic security threat, compromising aerospace power and undermining flight safety. This assessment is based on the theoretical study of threats as described by new concepts of war developed through the evolution of strategic thinking, such as post-modern wars, omnidimensional warfare, unrestricted warfare, Fourth Generation Warfare (4GW), and asymmetric warfare, the physical characteristics of laser, and the ramifications of its impact on biological tissues.

In Brazil, occurrences of lasers lighting aircraft are voluntarily filed via notification forms on the Brazilian Air Force's (FAB) Aeronautical Accidents Investigation and Prevention Center (CENIPA) website, which automatically records them as cases. They contain personal information about the occurrence reported: information about the aircraft and location of the occurrence; flight phase; laser color, number of beams and direction; intentions of the emitting source, and consequences for the pilot's visual acuity (distraction, false image formation, glare, temporary blindness, retinal burn, and/or retinal hemorrhage). Based on information from CENIPA, this study surveyed laser beam incidents involving military and civil aircraft in Brazilian airspace between 2012 and 2014 (totaling 4,877 incidents), to demonstrate laser's potential not only to cause air accidents, but to compromise the FAB's forecasted mission per the National Defense Strategy (END–acronym in Portuguese) as well.[1]

The tactical freedom of action of irregular forces, their growing sophistication, combined with the spread of modern technology, has brought a new era in terrorism and mass murder through laser and chemical, biological, and/or nuclear weapons.[2] The study on the ramifications of the use of lasers in Brazilian airspace in the pursuit of flight safety and aerospace power, may serve to

further stimulate future considerations on the forms of protection against the effects of laser.

Thus, the relevance of this study is to impart Air Force leadership with the importance of understanding the current laser beam incident situation in Brazil; the risk to which airplanes are exposed, especially pilots; and to pay heed to the need for preparation when its being used offensively with greater power, inside or outside national territories.

The Laser Threat, 4GW and Terrorism, and Flight Safety

The Laser Threat

American scientist Theodore Harold Maiman created the first laser on May 16, 1960 from a synthetic ruby bar. Technological advances have made it possible to create lasers with different powers; and their application diversified in several areas, such as defense, private industry, medicine and research.[3] The concern with the possible damage caused by laser started since its creation when its use was limited to large institutions, which started the first drafts on laser standardization and classification. In the US, the first safety limits for laser were developed for use in the military, between 1962 and 1963.[4]

In the late 1960s, American civilian organizations began to speak out on the need for laser exposure limits, and the US Department of Labor asked the American National Standards Institute (ANSI) to act on this issue. In 1973, ANSI issued the ANSI Z136.1 standard on laser's potential to cause biological damage.

The electromagnetic spectrum is composed of all types of electromagnetic energy such as radio waves, microwaves, infrared, visible, ultraviolet and gamma rays. This classification is determined by the wavelength of each type of electromagnetic energy. Lasers are usually infrared, with a wavelength of 1 mm at 750 nm, while the visible light spectrum ranges from 750 nm to 400 nm. The diffraction of an electromagnetic wave depends on its wavelength and the size of the opening. Considering the same aperture, lasers diffract 10,000 times less than microwaves and this allows its beam to have long range while keeping a small point of energy focused on the target.[5]

The difference between the light from a laser and the light from a lamp consists of spatial and temporal coherence. In a lamp, light emits photons equally in all directions. The light is random, out of phase and with multiple wavelengths. In contrast, laser beams emit a coherent light, that is, where photons travel in the same direction and phase. Laser beams are monochromatic and therefore have only one wavelength. Another important difference is that laser light is collimated, which means that the laser beam travels long distances with minimal dispersion.[6]

Depending on its properties, a laser beam falling on an object can have part of its energy absorbed, thus increasing the object's surface and/or interior temperature, potentially causing a change or deformation of the material.[7] This thermal effect can be harmful to tissues in the human body, according to the wavelength and power of the laser. Generally, eyes are more vulnerable to injuries by laser radiation than skin.[8]

Rapid exposures to low-radiation lasers usually result in temporary visual impairment. Weak lasers, like laser pointers, can typically impair night vision, while stronger lasers can also affect both day and night vision. The severity and duration of the impairment will depend on the laser's wavelength, the individual's ability to adapt to changes in light, whether photosensitizing medications were used, and eye color.[9] While low-energy lasers can have disruptive effects, those with higher energy can be destructive, causing damage to eye tissues since they can burn low-density objects. Regardless of the type of laser, criminals, paramilitary fighters, and terrorists can use it.[10]

Lasers are used outdoors for a variety of purposes, such as concerts and casinos to attract and entertain the general public, for research in astronomy, and in defense systems to aim, pursue, and destroy military targets. Over time, lasers have become less expensive and more accessible, and are now found in rifle and handgun sights, laser pointers for presentations, and for industrial use, with greater power, in the commercial market.[11]

When not used responsibly, laser beams can be dangerous and inspire concern, especially regarding its use in airspace. In the 1990s, there were several cases of laser illumination strikes against aircraft, civil and military crews, athletes in athletic competitions, and vehicles on highways.[12] Specifically, in the military, the laser beam can represent a critical factor for the success of the mission. Any laser beam that can strike military personnel in the exercise of their functions, whether in the air or on the ground, regardless of its power, should be considered a possible threat. For aviation, this threat is even greater, since while a visual disturbance caused by the laser in an infantryman can compromise his or her ability to fight, on a pilot it can lead to an aviation accident, claiming the lives of multiple personnel.[13]

The danger of this threat increases substantially when the targets are civilian, private, cargo transport, and police aircraft. Loss of vision and visual references can result in catastrophic injury and loss of life for both crew and passengers, as well as endangering people on the ground.[14]

4GW and Terrorism

War is an ancestral phenomenon and history has shown that its motivation (envy, hatred, arrogance, greed) is the same regardless of the actors who lead it: tribes, mercenaries at the service of the crown, city-states, terrorist states and/or groups. War represents a conflict of ideas and is characterized by its political-social, economic, geographical, geopolitical, religious, cultural and historical context. The nature of war is perennial, that is, constant, changing only according to changes that take place in the way of fighting, for whom they fight, or those who fight. These changes, in turn, occur due to relevant changes in the political-social organization, the means to achieve the ends, the application of technology, and the organization and tactics of the armed forces.[15]

Notwithstanding the emergence of the Revolution in Military Affairs (RAM) in the second half of the twentieth century, when the computer revolution made possible the integration of nuclear warheads with intercontinental ballistic missiles - whose use could drastically decrease the time of war – RAM is not restricted to the technological evolution of armaments and military equipment, nor to the way they are used.[16] As a complex phenomenon, RAM has four dimensions: technological, organizational, conceptual and doctrinal. New equipment that demands new military organizations to combat new threats, in a constant cycle of indeterminate growth, has generated new strategic approaches, which constitutes the conceptual scope of RAM.[17] The new threats present in the ongoing RAM are global terrorism, weapons of mass destruction and transnational organized crime. Their fight would give rise to wars under a new paradigm, called postmodern or 4GW, in which states fight against non-state actors, characterized as asymmetric conflicts.

Lind developed the 4GW concept, predominantly at the tactical level and, complementarily, at the operational level. It describes four generations of war whose succession begins with the Peace of Westphalia of 1648, obtained by the treaty that ended the Thirty Years' War, from which the State established the monopoly of war.

According to Lind, the first generation of modern warfare, line-and-column warfare, in which the battlefield was orderly and formal, lasted approximately between 1648 and 1860, reaching its peak in the Napoleonic wars. The wars of the first generation were characterized by being waged by conscript national armies, contrary to what happened in previously, when wars were conducted by nobles and mercenaries more or less faithful to the crown, depending on the amount of gold received in return. The first generation created a military culture of order. However, in the mid-nineteenth century, the battlefield began to be-

come disordered, given that the line and column tactics, which presupposed armies in concentrated masses, became obsolete. Thus, the culture of order became increasingly incoherent.[18]

Second-generation warfare was developed during the First World War, when the use of artillery quickly made line-column tactics obsolete and the battlefield disorganized. In it, in which the doctrine was summarized by the French as "the artillery conquered, the infantry occupies", firepower was carefully synchronized between tanks and artillery in a conducted battle, where the commander acted as a conductor. Preserving the culture of order, the focus was turned inward, on rules, processes and procedures, in which obedience was more important than the initiative.[19] This doctrine is still present in the US Army and Marine Corps today, as demonstrated in the wars in Afghanistan and Iraq, but with aviation replacing artillery as a source of firepower.

Third-generation warfare manifested itself superbly after the Second World War, with the development of the German Army's blitzkrieg doctrine. Also known as maneuver war, it was based on speed and surprise, instead of firepower, in which the objective was no longer to approach and physically destroy, but to collapse or annul enemy forces, under the motto: bypass and collapse instead of close in and destroy.[20] It was also characterized by using psychological warfare and infiltration tactics of the enemy's rear by its weak flanks. The blitzkrieg principle was used by the United States to achieve a quick victory over Iraq in the 1991 Gulf War. In addition to raising questions about tactics, the third-generation war also raised questions about the values of military discipline and hierarchy; in this model, initiative became more important than obedience, as well as self-discipline (endogenous) in the face of imposed discipline (exogenous).

The 4GW comprises the most radical changes since the Peace of Westphalia. After World War II, during the Cold War, there was a notable increase in asymmetric wars and terrorist actions. Great powers started to sponsor irregular local forces, which were less costly, and saved them from criticism from public opinion and political wear and tear. However, states lost their monopoly on war, which brought new threats to international security, and its armed forces began to fight non-state opponents such as al-Qaeda, Hamas, Hezbollah, the Revolutionary Armed Forces of Colombia (FARC), the Islamic State, and so forth, which do not follow the Hague and Geneva conventions, and whose fighters present little difference between civilians and soldiers. The 4GW returns to a pre-Westphalian world of clashes between cultures, but not merely of the countries in conflict: an invasion of immigrants can be as seen as the invasion of an enemy army, and causing low intensity conflicts to prevail.[21] Corroborating the 4GW concept, Van Creveld states that the war has evolved to the point where

Clausewitz's theory has become obsolete.[22] For him, in the future, conventional combat will cease, and wars will become low-intensity conflicts.

The concept of terrorism is nebulous and controversial,[23] which can be explained by two factors. The first consists of the very history of the creation of the term terrorism, given that the meaning and use of the word have changed over time. For Bruce Hoffman,[24] during the French Revolution, the term terrorism had a positive connotation, associated with the ideals of virtue and democracy; however, five years after the French Revolution, with the execution of Robespierre, terrorism had become a term associated with the abuse of power. Additionally, changes in the term terrorism throughout history refers to its anti or pro state connotation. While the *Narodnaya Volya* (Popular Will) rebels in late 19th-century Russia were clearly anti-state, in fascist Europe in the 1930s, the practices of mass repression employed by totalitarian states and their dictatorial leaders against their own citizens were described as state terrorism.[25]

The second factor that explains the cloudiness that characterizes the term terrorism, refers to the diversity of political interests that are at work in the world. Hübschle describes[26] terrorism as being a negative term generally applied to enemies and opponents. Thus, any concept of the term terrorism is dependent on the political functionality that one wants to give it. In other words, political actors insert themselves in each political-cultural configuration that conditions their concept of terrorism, according to their political interests. So, for example, the US Department of State conceptualizes terrorism as premeditated violence against noncombatant targets by subnational groups, usually designed to influence an audience.[27] In other words, it is a connotation that meets the policies to combat terrorism carried out by the American State while it rejects accusations of the practice of terrorism against it.

One of the principles of the Brazilian Constitution, in international relations, is the repudiation of terrorism. More recently, Law No. 13.260, of May 2016, amends Laws 7.960, of December 21, 1989, and 12.850, of August 2, 2013, and regulates the provision in item XLIII of article 5 of the Federal Constitution, disciplining terrorism, dealing with investigative and procedural provisions, and reformulating the concept of a terrorist organization.[28] According to Article 2 of Law No. 13260, of May 16, 2016, terrorism:

> "... consists of the practice by one or more individuals of the acts provided for in this article, for reasons of xenophobia, discrimination or prejudice of race, color, ethnicity and religion, when committed with the purpose of causing social or generalized terror, exposing danger to person, property, public peace or public safety."[29]

Brazil's anti-terrorism combat structure includes several agencies. According to the END, the prevention of terrorist acts and massive attacks on human rights, as well as the conduct of counterterrorism operations, falls under the Ministries of Defense and Justice and the Institutional Security Office of the Presidency of the Republic (GSI-PR). For the Ministry of Defense, prevention is under the responsibility of Armed Forces Command; at the Ministry of Justice, under the tutelage of the Federal Police Department; while at GSI-PR, which has ministry status, the responsibility for controlling these threats lies with the Brazilian Intelligence Agency (ABIN).[30]

Currently, any definition of terrorism must consider the main political event of modernism: the emergence of the modern nation-state, consolidated by the Treaty of Westphalia, in 1648. Since the advent of this central political institution, in which the world has become interstate or international, the concept of terrorism is based on the attack against, ultimately, the state, or at least the government of the state. And the more this government acts in a context of democracy and the preservation of the rule of law, the more the attack is characterized as terrorist.

Thus, terrorism can be defined as a threat and/or a practice of premeditated violence undertaken by non-state subnational groups against non-combatant subjects, normally intended to influence an audience (that is, the target is not only the immediate victim), which aims at political ends, particularly to change or constrain state behavior. By this definition, it is easy to understand the reason for the treatment given to the fight against terrorism as a matter of national defense.

Technological advances have enabled the creation of weapons (precision and non-lethal) that reach the enemy's nerve center with fewer side effects, offering more options for victory in which the enemy's control overcomes the need for their annihilation. These weapons have been labeled as kinder; but does not mean that they have lost their effectiveness in the battlefield. For example, missiles used to cancel the combat capabilities of a battle tank, or the use of a laser beam to destroy its optical equipment or even just blind its crew, as in the battlefield, someone who is injured requires more care than someone who is killed.[31]

Compromising the psyche of the enemy regardless of the medium used is the objective of the main non-state agents involved in 4GW. The use of the laser beam as weaponry can temporarily or permanently incapacitate a soldier, or cause further destruction depending on its power. Regardless of wars in the future, the use of lasers will be a threat in the theater of operations, or at long-distances, and will be carried out by states and/or non-state agents. To prepare our troops with adequate protection is to anticipate the enemy's action and maintain the integrity of the combatants for the duration of the conflict.

Flight Safety and Aerospace Power under the Threat of Laser

Vision is the main sense involved in spatial orientation. Vision is essential in all phases of flight and makes possible the identification, shape, and color of objects at a distance. Vision occurs through a complex physiological and psychological process that depends on the interpretation of signals captured by the eyes and transmitted to the brain. Environmental stresses can disturb the physiological functioning of the eye, thus compromising the maintenance of normal vision.[32]

Adequate lighting is necessary for all tasks that require vision. Excessive light, however, can affect vision to the point of rendering it ineffective. In aviation, a pilot can experience high levels of lighting when flying towards the sun or looking at very bright artificial light sources, such as searchlights. And now, the laser has become an integral part of the high intensity light problem in aviation.[33]

In 1988, in its report on Medical Management of Combat Laser Eye Injuries, the US Air Force indicated that in future combat, lasers would be used directly against their forces and that their effects on crew health and performance were of particular concern.[34]

The rapid growth in laser development has increased its use in the military, such as laser designators and rangefinders, which are used by ground troops, tanks, aircraft, ships and anti-aircraft artillery. Their use, even in exercises, can also cause accidental eye injuries. The laser energy in this equipment is enough to cause eye damage from miles away. Visible and near-infrared lasers threaten even crews protected by canopies, while ground defense forces are susceptible to ultraviolet lasers.[35]

In 1995, Protocol IV was added to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons that can be excessively harmful or can Generate Indiscriminate Effects (CCAC), held in Geneva on October 10, 1980. This protocol prohibits the use of laser weapons whose primary purpose is to cause permanent blindness.

When a photon is absorbed, biological damage can occur because of one of three main injury mechanisms, or any combination of them. They are photochemical (photolytic), thermal (photo coagulator), and/or mechanical-acoustic.[36] The human eye is more vulnerable to this damage than the skin. The cornea is the most anterior structure of the human eye and unlike the skin, it does not have an outer layer of dead cells as protection. The cornea can absorb and be injured by laser energy with wavelengths shorter than ultraviolet (<300nm) and longer than infrared (> 1400nm). The lens of the eye is vulnerable to lasers near ultraviolet and infrared levels. However, the most worrisome is the exposure to lasers that cross the optical medium

from the eye to the retina, with wavelengths ranging from 400 to 1400nm, including the entire visible portion of the optical spectrum. The worst case occurs when a direct or reflected laser beam enters the eye.[37]

The energy density of the laser beam can be increased 100,000 times by the focusing action of the eye. Thus, if the irradiance that penetrates the eye is 1 mW/cm2, the irradiance on the retina will be 100 W/cm2. Looking directly at a laser beam through binoculars or other image magnifying devices, depending on the power of the laser, can substantially increase eye damage.[38]

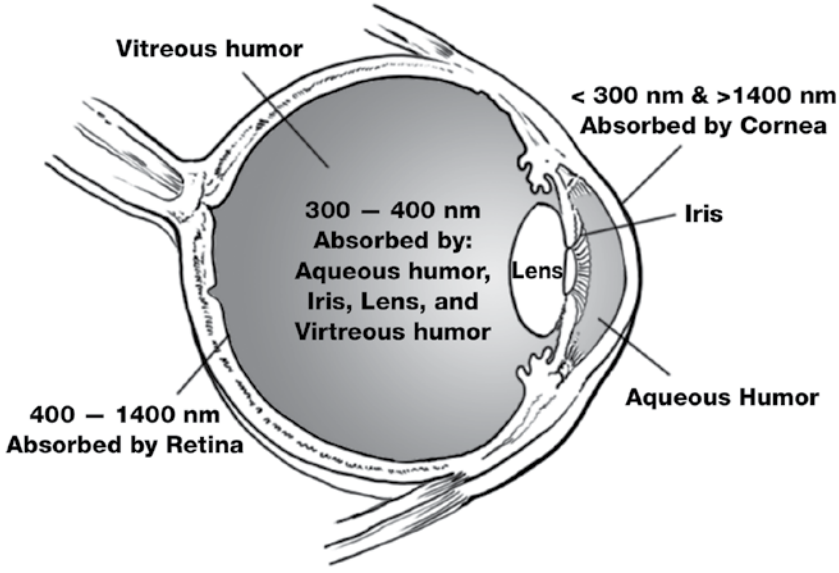

Figure 1. Absorption of optical radiation by ocular structures
Source: Author

Eye damage caused by laser can be classified into retinal or non-retinal according to the incident laser beam energy. Laser beams with wavelengths in the visible range of the electromagnetic spectrum (400-700nm) and close to the infrared (up to 1400nm) usually pass through the eye media (cornea, aqueous, crystalline humor, vitreous humor) and focus their rays on the retina; while laser beams in the ultraviolet range and above 1400nm are absorbed by the anterior tissues of the eye, such as the cornea and the lens, before reaching the retina (Figure 1).[39]

It is possible to define a wide range of potential biological effects involving laser radiation range, including both pathological damage (reversible or irreversible) and

impacts on performance that pose a threat to safe air operations. This ranges from distraction, glare, flash blindness, afterimages and residual scotomas, to retinal burns, retinal hemorrhages, and even eye perforation. It also includes physical and psychological phenomena that can further disturb visual and cognitive functions during a given task (Figure 2).[40]

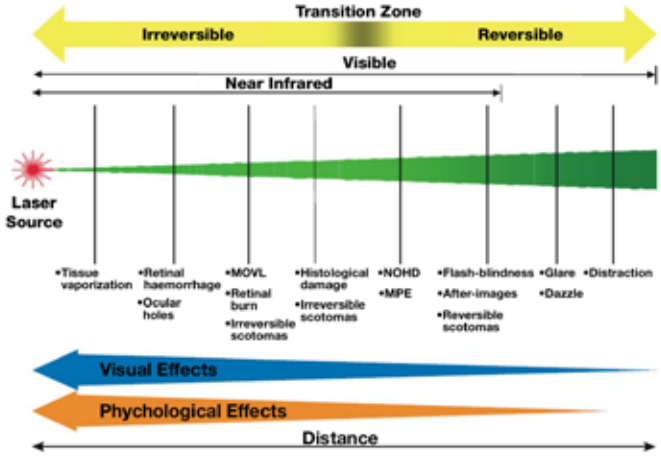

Figure 2. Variation of the biological effects of laser rays.
Source: Author

In the US, a variety of laser safety standards are available, including federal and state regulations. The most frequently applied guidelines are in the ANSI Z136 series. ANSI Z136.1, American National Standards for Safe Use of Lasers, defines recommended guidelines for the safe use of lasers with a wavelength between 180nm and 1000μm, and classifies each type of laser by its potential for biological damage. Laser classes vary from the lowest (class 1) to the highest (class 4) risk of biological damage. The letter M, which appears after the number of some classes, refers to the use of optical resources at the time of exposure which can magnify the laser's energy.

Military lasers are lasers or laser systems used in combat, combat training, or classified in other areas of national security interest, which require approval by the USAF Laser System Safety Review Board for their acquisition and use. Examples of laser for military use are laser illuminators, laser designators, range finders, tactical tips, tactical lasers, and lasers used to increase artillery firepower. Lasers classified as Direct Energy Weapons (DEW) are under the aegis of Air Force Instruction (AFI) 91-401 (Directed Energy Weapons Safety).[41]

USAF AFI 48-139 assigns aerospace medicine as the office of primary responsibility on the use of flight certified Laser Eye Protection (LEP) authorized in AFI

11-301, volume 4, Aircrew Laser Eye Protection (ALEP), examination, treatment, and monitoring of military personnel suspected of long exposure to lasers or other sources of optical radiation; and to assist in the investigation of these cases.

In 1999, the International Civil Aviation Organization (ICAO) created a study group to assess laser risks and whether new standards or recommended practices (SARP) would be needed. Between 1999 and 2000, the ICAO aviation medicine secretariat, together with the assistance of the study group, developed SARP on lasers that are now included in annexes 11 and 14. In 2003, ICAO published the Manual on Laser Emitters and Flight Safety (DOC 9815) on the clinical, physiological and psychological effects of air crew exposed to laser emitters.[42]

Flight Safety is the state in which the possibility of damage to people or property is reduced to an acceptable level or below, through an ongoing process of hazard identification and risk management.[43] Lasers can be considered a hazard, the risk management of which is based on the elaboration of measures to reduce the possibility of consequences to air operations, such as the establishment of protection zones around the airfields.

In many articles, issued especially by the Federal Aviation Administration (FAA), the US agency responsible for calculating laser incidents in the US, it was noted that the main objective was to alert the aeronautical community about the risks of eye damage to crews inadvertently hit by laser beams and how it affects flight safety, in addition to establishing ways to prevent these incidents and/or the injuries themselves. Ways to reduce the number of incidents and eye damage include preventing procurement of restricted laser equipment, the establishment of specialized protection for each type of laser beam, and procedures to counteract laser intrusion in the cabin. If there is a threat, eye protection specific to each type of laser beam, among other countermeasures, such as crew training, are the only ways to prevent eye damage and accidents.

Brazilian statistics of laser occurrences and their consequences

To demonstrate the laser's potential to compromise the FAB's mission, the following data were studied from the total of 4,877 occurrences recorded on the CENIPA website from 2012 to 2014: occurrences by state, airfield, type of operator, distribution of occurrences per year, laser color, number of emitting sources, phase of the flight, types of consequences, time of occurrence and intentionality of the laser emitting source.

During this same period the FAA registered 11,336 occurrences in the US, according to an analysis carried out by laserpointersafety.com (Figure 3).

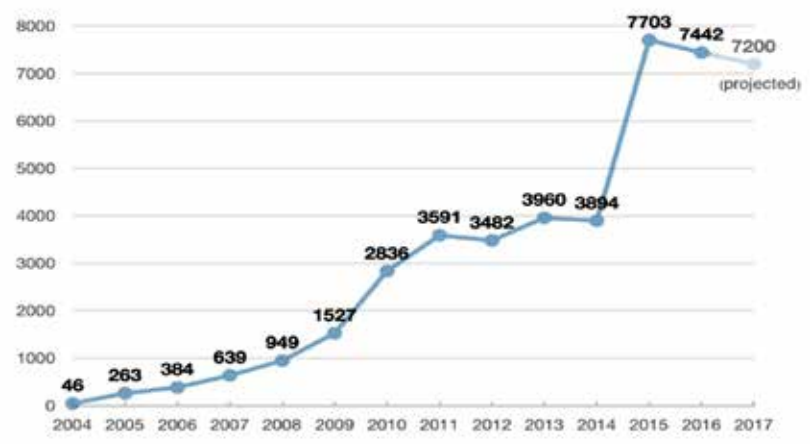

Figure 3 - Notifications of laser illuminations at the FAA by year
Source: Laser PointerSafety.com, 2017

According to FAA air traffic statistics, the North American aircraft fleet is much larger than the Brazilian: 5,000 aircraft in the sky at any time; of which 164,200 are fixed-wing, 10,500 are helicopters, 6,676 are commercial jets, and 35,300 are experimental and light sport;[44] compared to 21,905 aircraft registered in the Brazilian Aeronautical Register, of which 5,516 are experimental, according to the most recent statistics from the National Civil Aviation Agency (ANAC),[45] of which 735 are from Brazilian armed forces distributed among the FAB (573), the Brazilian Army (83) and the Brazilian Navy (79).[46]

Proportionally, the occurrences in Brazil were more frequent in civil aviation. Seventy-eight percent of the occurrences (3,804) occurred with civil aviation aircraft, 9 percent with military aircraft, and 13 percent undetermined. The states with the highest incidence of occurrences were São Paulo and Minas Gerais in 2012 and 2013, and São Paulo and Espírito Santo in 2014. In the state of São Paulo, Campinas and Guarulhos airports stood out.

The number of occurrences decreased over the years, most significantly in 2014, after two years of disclosure by CENIPA and the Regional Services for Investigation and Prevention of Aviation Accidents. In accordance with the latest official FAA survey,[47] which analyzed laser illumination against aircraft between 2004-2008, most exposures occurred at night and the green laser was the most frequently used against aircraft, about 97 percent.

Most of the occurrences were observed in the final approach phase (53 percent), as the aircraft are closer and more easily detected in the visual field of people who are in the vicinity of the airfield. Only one emitting source was identified in 90 percent of

the occurrences, and 90 percent of personnel who filed the incident with CENIPA believed that the use of the laser beam was intentional. This corroborates the theory that lasers can be used as weapons, and that easy access and lack of control make its use dangerous, and with great potential to become a threat to flight safety, FAB operations, and the sovereignty of Brazilian airspace.

Impacts to vision are the medical concern that affects human performance with machines, in this case the aircraft, and all the problems that arise from this interfere in the FAB's mission accomplishment. Distraction and glare were the most reported visual consequences, with 74 percent and 25 percent, respectively. There were no reports of permanent eye damage.

Final Considerations

According to previous studies, the biggest concern with these types of occurrences is effect on crews exposed to laser during landing and take-off procedures,[48] considered critical moments of air operations.[49] As noted in the present research, 53 percent of aircraft lighting cases in Brazil occurred on final approach. It is during this phase that the pilot must have adequate vision to perceive the start of the track or runway. Lighting the cockpit by laser beams can cause temporary visual impairment just like other effects such as glare, afterimages, and flash blindness, in addition to causing distraction, disturbance, disorientation, all representing a risk to flight safety.

Compliant with AFI 11-301v4,[50] the selection of an LEP must follow the following criteria: the type of laser, the type of protection available, and side protection. Information about the type of laser used in a threat environment will depend on an intelligence unit to assist crews in the theater of operations. Flight protection professionals should inform crews on the specific ALEP wavelength protection characteristics available for use. Some protection devices are available with or without side protection. ALEP with side protection is required for protection against reflected laser in aircraft lighting cases and can be used with night vision goggles for protection against lighting outside the visual axis.

The big question presented in this article is whether laser poses an aviation security and safety threat. Although no laser-caused aerial incident has been attributed to a terrorist attack, security institutions such as the US Federal Bureau of Investigations have followed the interest of non-state actors in lasers with great potential for blindness. In order to corroborate this theory, this article's research indicated that about 90 percent of the incidents were intentional.

Despite reported visual incidents, distraction being the most common, according to Harris,[51] eye injuries caused by laser beams are often not reported and, consequently, it is difficult to obtain an accurate assessment on the total number of cases. Additionally, many types of lasers are invisible, so personnel

may not realize that they have been exposed, which constitutes another reason for the poor estimate of these incidents.

No information was found regarding the first record of a laser beam incident in Brazilian airspace. However, what is known is that there was an increase in occurrences between 2010 and 2011, leading to CENIPA creating a laser notification form on its website in 2012, to be used by civilian and military aviators.

The CENIPA files represent the only attempt at national documentation of laser incidents in Brazilian airspace relating to ophthalmic damage. Thus, it can be used to analyze aspects applicable not only in the area of flight safety, but in the country's defense strategy and the maintenance of the Brazilian Aerospace Power as well. In Brazil, the use of laser beams against aircraft is a crime defined in Article 261 of the Penal Code: To expose a vessel or aircraft, owned or someone else's, to danger, or perform any act that tends to prevent or hinder maritime, fluvial or aerial navigation; under penalty of imprisonment, from two to five years.

Regarding Brazilian Aerospace Power, the inclusion of specific protection for pilots against laser rays, together with the prevention of these occurrences, may represent yet another form of maintaining the ability of crews to carry out air defense missions against external threats, such as at the country's borders or when called upon to reestablish law and order, as provided by the National Defense Policy and the END. ❑

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20. The swathes of land highlighted in black refer to ISIS control zones. They are defined by the ISW as areas where insurgents exert pressure—physical and/or psychological—on the inhabitants to ensure their obedience and submission. The areas marked by dark red are the attack zones from which ISIS conducts offensive maneuvers. In the support zones, represented by the lighter shade of red, there is not significant opposition to the insurgents, and they serve as a basis for logistical and administrative support from their forces. Finally, there are the Kurdish territories in Iraq, identified by the color green. These demarcations will also be present on the following maps. See "ISIS Sanctuary Map: October 30, 2014," Institute for the Study of War, http://www.understandingwar.org/backgrounder/isis-sanctuary-map-october-30-2014.

21. Although the first ISIS target cut-off time frame ends at the end of March, the nearest map of this period dates from April 3rd, while the insurgents' territorial situation wasn't reported until the 4th. The circles on this and the next maps only highlight some of the territorial changes already indicated in the areas determined by the legend, and do not reflect the size of the territories in which these changes occurred. See "ISIS Sanctuary Map: October 30, 2014," Institute for the Study Of War, http://www.understandingwar.org/backgrounder/isis-sanctuary-map-october-30-2014.

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