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Analysis of The Impact of Laser Beams on Aviation Safety in Sultan Mahmud Badarrudidin II International Airport

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ABSTRACT

This research was conducted to gain an understanding of the dangers of laser light on flight safety, especially during aircraft landings. It also aimed to explain the importance of the role of many related parties in providing education and information to the community around the airport about the dangers of laser light. This descriptive research, employing a qualitative approach, was intended to provide in-depth information. The unique perspectives of different parties, including air traffic controllers, operations, and safety managers, were instrumental in this. Some laser attacks can produce blinding bursts of light, which can be uncomfortable when flying. It will impair the pilot's judgment as there is a possibility of the pilot experiencing partial or total blindness, highlighting the severe consequences of such attacks. Contracting States may be guided by the following text examples when controlling the hazards of laser beam emissions or enacting regulations by Annexes 11 and 14. Flight safety can be achieved when all safety determinants are met, namely, carrying out several preparatory procedures and increasing the outreach to the community in the airport. The authorities can also take strict action, conduct public awareness campaigns, and educate the public. Pilots and crewmembers should report laser incidents as soon as possible to minimize risk.

INTRODUCTION

In an era where technology becomes increasingly accessible, the aviation industry faces a rising menace: laser strikes on aircraft. Initially dismissed as pranks, these incidents have grown in frequency and severity, drawing concern from pilots, airlines, and regulatory bodies worldwide. The intentional shining of lasers at aircraft, particularly targeting the cockpit, can lead to temporary visual impairment or distraction of pilots during critical phases of flight such as takeoff and landing. Over the past two decades, the availability of high-powered laser pointers has surged. These devices, which can emit a concentrated beam of light capable of reaching aircraft at cruising altitudes, have been misused with increasing frequency. According to the Federal Aviation Administration (FAA), incidents of laser strikes have escalated, with thousands of reports annually in the United States alone (FAA, 2022).

Aviation Law Number 1 of 2009 states that aviation safety is a condition of fulfilling safety requirements in airspace, aircraft, airports, air transportation, flight navigation, supporting facilities, and other public facilities. Sultan Mahmud Badaruddin II Airport, or SMB II Airport, is an international airport in South

Sumatra Province. The amount of traffic movement in the Aerodrome Control Tower Unit serves arrival and departure flights and local flights of around 50 traffic per day. The location of the airport, which is close to residential areas and fields, is one of the factors attracting the interest of sellers and the public in selling and buying lasers. Laser sellers can often be found in the area around the airport. The presence of laser strikes at low altitudes can cause blinding visual impairment or sudden blindness to pilots at critical phases of a flight, such as during landing or takeoff. Both visible and invisible laser beams can also cause damage to the human eye. Despite allegations of laser attacks on aircraft since the 1990s, formal investigations into the impact of these attacks were conducted in the late 2000s. Since then, there has been a continuous worldwide increase in insider knowledge reported. In the United States, there has been an increase in the number of insider attacks, which saw a jump of 2,293% from 311 in 2005 to 7,442 in 2016. Even more concerning is that the number of laser attacks in Great Britain has increased by 4,093% since 2007. In 2007 there were 30 cases, but in 2016, there were 1,258 documented laser attacks. These figures come from a study published by Euro control in 2011. According to the British Airline Pilots Association, fifty-five percent of its members were victims of laser attacks in 2015, with four percent having six or more laser attack events—this kind. However, even though some state and airline authorities have carried out various measures, the number of laser attacks on aircraft is constantly increasing. These efforts have not stopped this increasing trend of laser attacks (Aritonang & Juhana, 2018).

In August 2021, a commercial airliner on its final approach to Philadelphia International Airport was struck by a green laser, illuminating the cockpit and startling the pilots. The aircraft, carrying over 150 passengers, was at a critical moment of its descent when the incident occurred. Quick action by the flight crew, who managed to shield their eyes and maintain control, averted a potential disaster. This event serves as a stark reminder of the dangers posed by laser strikes (Smith, 2021).

Here are laser strike reports to the FAA from 2016 until 2023.

Table 1. Laser Strikes Reported to FAA

No	Year	Laser Incident
1	2023	13,304
2	2022	9,457
3	2021	9,723
4	2020	6,852
5	2019	6,136
6	2018	5,663
7	2017	6,754
8	2016	7,398
Total		65,287

Source: faa.gov

Based on reported laser incidents for 2023, it can be known that 34 laser attack events caused injury out of a total of 13,304 incidents. These events can be seen in Table 2

Table 2 Incidents 2023

No	Incident Date	Incident Time	Flight ID	Aircraft	Altitude	Airport	Laser Color	Injury	City	State
1	4-Jan-23	0110	N265LH	BK17	1800	LIT	Green	Yes	Little Rock	Arkansas
2	7-Feb-23	0315	HATED75	UH60	1500	WOC	Green	Yes	Washington	District of Columbia
3	3-Mar-23	0603	EAGLE1	HELO	6500	D01	Blue	Yes	Denver	Colorado
4	22-Mar-23	0657	N673W	C56X	10000	MDT	Green	Yes	Harrisburg	Pennsylvania
5	31-Mar-23	1030	N214NX	PC12	4000	ZSE		Yes	Auburn	Washington
6	18-May-23	0433	NVT31	AS50	9000	ELP	Green	Yes	El Paso	Texas
7	23-May-23	0315	UPS785	B752	6000	ELP	Green	Yes	El Paso	Texas
8	2-Jun-23	0509	HEX33	H60	1600	NZY	Green	Yes	San Diego	California
9	24-Jun-23	0135	JIA5487	CRJ9	7000	CLT	Green	Yes	Charlotte	North Carolina
10	4-Jul-23	0243	N3512X	M20P	3000	ZHU	Green	Yes	Houston	Texas
11	5-Jul-23	0545	N7967C	P28A	4500	GEG	Green	Yes	Spokane	Washington
12	8-Jul-23	0116	ICE55L	B38M	2000	JFK	Green	Yes	New York	New York

13	20-Jul-23	0250	AAL2237	A321	10000	A80	Green	Yes	Peachtree City	Georgia
14	21-Jul-23	0445	NKS913	A320	2400	LAX	Green	Yes	Los Angeles	California
15	2-Aug-23	0226	AAL648	A320	3000	IND	Green	Yes	Indianapolis	Indiana
16	11-Aug-23	0335	DAL1003	A321	6000	SLC	Green	Yes	Salt Lake City	Utah
17	26-Aug-23	0325	DAL1633	A319	2000	IAH	Green	Yes	Houston	Texas
18	13-Sep-23	0200	N64367	C172	4500	D10	Green	Yes	Dallas-Fort Worth	Texas
19	16-Sep-23	0250	CAP4032	C182	3000	FSD	Green	Yes	Sioux Falls	South Dakota
20	21-Sep-23	0104	CTL9	AC50	1200	MKC	Green	Yes	Kansas City	Missouri
21	5-Oct-23	0035	N80914	C172	1800	LGB	Green	Yes	Long Beach	California
22	7-Oct-23	0317	MRA643	C208	6000	ZFW	Green	Yes	Fort Worth	Texas
23	10-Oct-23	0131	ENY3541	E170	3000	SGF	Green	Yes	Springfield	Missouri
24	14-Oct-23	0311	SKW5702	E75L	3000	LFT	Green	Yes	Lafayette	Louisiana
25	24-Oct-23	0248	ENY3336	E170	23000	ZTL	Green	Yes	Hampton	Georgia
26	24-Oct-23	0425	ENY3336	E170	23000	ZTL	Green	Yes	Hampton	Georgia
27	24-Oct-23	1522	NKS1084	A320	9000	CLE	Green	Yes	Cleveland	Ohio
28	28-Oct-23	0035	RPA3568	E170	3700	AVP	Green	Yes	Wilkes-Barre/Scranton	Pennsylvania
29	8-Nov-23	0100	DAL2891	B717	8000	MSP	Green	Yes	Minneapolis	Minnesota
30	13-Nov-23	0213	SCX3058	B737	8300	SCT	Green	Yes	San Diego	California
31	13-Nov-23	1050	ASA536	B739	10300	A90	Green	Yes	Merrimack	New Hampshire
32	23-Nov-23	0321	UCA4333	E145	8000	CRP	Green	Yes	Corpus Christi	Texas
33	30-Nov-23	0529	LN820SF	B407	2900	LIT	Green	Yes	Little Rock	Arkansas
34	11-Dec-23	0154	N48RG	C172	2700	ZME	Green	Yes	Memphis	Tennessee

Source: faa.gov

Based on Table 2 above, the reports of laser attack incidents that caused injury throughout 2023 are dominated by green laser color, with a total of 32, 1 blue laser color, and one blue and purple laser color. Of the 2023 reports, the most laser color is green, with more than 11 thousand reports, and the second most color is blue. In addition to green and blue, several laser colors have been included in the report, such as red, unk, white, purple, and orange.

Based on the procedure, the type of services LPPNPI Branch Palembang or AirNav Palembang has the kind of Aerodrome Control Tower (TWR) and APP (Approach Control Surveillance). Since 2016, a total of 15 cases of laser attacks have been reported from AirNav branch offices. Throughout the previous year, 213 laser attacks were recorded in 15 central intermediate and primary branches of AirNav throughout Indonesia. Based on these conditions, the author will examine the dangers of using lasers fired toward the cockpit of aircraft at Sultan Mahmud Badaruddin II Airport. Events of laser use carried out by the community around the airport often occur, especially during night conditions. The primary danger of a laser strike is the temporary visual impairment it can cause. Pilots affected by laser strikes report experiences of flash blindness, glare, and afterimage — all of which significantly impair their ability to perform flight duties. The distraction and potential for panic are hazardous during landing or in adverse weather conditions, where pilot focus is paramount.

METHOD

This research is descriptive research using a qualitative approach. This qualitative approach is intended so that the research background provides more in-depth information. Qualitative research is research that intends to understand the phenomenon of what is experienced by research subjects, such as behaviour, perception, motivation, action and others, holistically and by way of description in the form of words and language, in a particular natural context and by utilizing various natural methods (Moleong, 2017).

Many laser attacks have been launched at the air base owned by Sultan Mahmud Badaruddin II. It was decided to collect information about laser attacks by having conversations and making observations. It is essential to participate in the interview in order to give a full explanation of the phenomenon by collecting related information. This information can only be done by talking to as many people as possible.

To gather information about laser attacks and to share their observations about events that might influence the occurrence of such attacks with appropriate parties, many sources have been interviewed,

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including air traffic controllers, operations and safety managers. This has been done to share their observations with the right parties.

RESULTS AND DISCUSSION

A *laser* is a light source that utilizes cutting-edge science and technology to create highly concentrated, coherent, and monochromatic light, as stated in the Big Indonesian Dictionary (KBBI).

A laser, an acronym for Light Amplification by Stimulated Emission of Radiation, is a device that generates a beam of coherent light through the process of optical amplification. The fundamental principle behind laser operation is stimulated emission of electromagnetic radiation, a quantum mechanical phenomenon predicted by Albert Einstein in the early 20th century. Unlike ordinary light sources, which emit incoherent light, lasers emit light that is spatially and temporally coherent. This coherence allows laser beams to be focused to very tight spots, making them useful in a variety of applications, from optical disk drives and laser printers to surgical and material cutting processes (Svelto, 2010).

A laser attack on an aircraft cockpit occurs when an individual deliberately shines a laser pointer at an aircraft, particularly aiming at the cockpit with the intent to distract or temporarily impair the vision of the pilots. These attacks pose a significant safety risk, especially during critical flight operations such as takeoff, landing, or when flying at low altitudes. The main hazard of a laser strike is the potential to cause flash blindness, glare, or afterimages for the pilots, compromising their ability to safely control the aircraft. The severity of the effect can vary based on the laser's power, wavelength, and the duration of exposure. Since the early 2000s, there has been a notable increase in reported incidents of laser strikes on aircraft, prompting aviation authorities worldwide to implement stricter regulations and penalties to deter such actions (Federal Aviation Administration, 2021).

Components of a laser, as shown in figure 1, the three basic components of laser are:

1. Lasing medium (crystal, gas, semiconductor, dye, etc.)
2. Pump source (adds energy to the lasing medium, e.g. xenon flash lamp, electrical current to cause electron collisions, radiation from another laser, etc.)
3. Optical cavity (typically bound by reflectors to act as the feedback mechanism for light amplication)

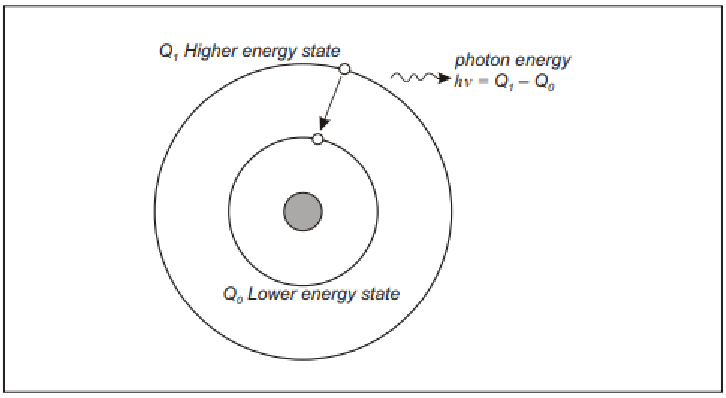

Figure 1. Emission of radiation from an atom by transition of an electron from a higher energy state to a lower energy state

Electrons in the atoms of the lasing medium normally reside in a steady-state lower energy level. When energy from a pump source is added to the atoms of the lasing medium, the majority of the electrons are excited to a higher energy level, a phenomenon known as population inversion. This phenomenon must occur in order to achieve light amplification. There are a number of methods used in producing laser energy. Common methods include the use of semiconductors, liquid dye, solid state, gas and metal vapour. Although the technology behind each type can be quite different, the resulting laser energy has the same basic characteristics (see Table 2). In recent years, the semiconductor laser (laser diode) has become the most prevalent laser type. The laser diode is a light emitting diode (LED) with an optical cavity to amplify the light emitted from the energy band gap that exists in semiconductors (ICAO, 2003).

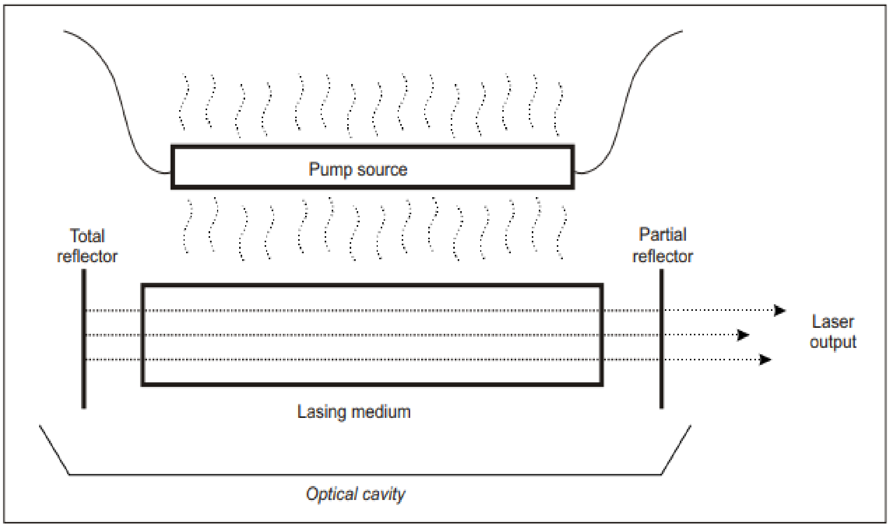

Figure 2. Diagram of solid state laser

Table 3
Examples of common lasers

No	*Lasing Medium*	*Laser Method*	*Spectral Region*	*Wavelength*
1	Argon fluoride	Gas	UV	193 nm
2	Xenon chloride	Gas	UV	308 nm
3	Helium cadmium	Gas	UV Blue	325 nm 442 nm
4	Argon	Gas	Blue Green	488 nm 514 nm
5	Krypton	Gas	Blue Green Yellow Red	476 nm 528 nm 568 nm 647 nm
6	Copper vapour	Metal vapour	Green Yellow	510 nm 578 nm
7	Frequency-doubled Nd-YAG	Solid state	Green	532 nm
8	Helium neon	Gas	Green Yellow Orange Red Near IR	543 nm 594 nm 612 nm 633 nm 1.15 μm
9	Rhodamine 6G	Liquid eye	Visible	550-650 nm
10	Gold vapour	Metal vapour	Red	628 nm
11	Gallium alumunium arsenide	Semiconductor	Visible – near IR	670-830 nm
12	Ruby	Solid state	Red	694 nm
13	Alexandrite	Solid state	Near IR	700-815 nm
14	Gallium arsenide	Semicondutor	Near IR	840 nm
15	Titanium sapphire	Solid state	Near IR	840-1100 nm
16	Nd: YAG	Solid state	Near IR	1.06 μm
17	Erbium:glass	Solid state	Mid IR	1.54 μm
18	Erbium:YAG	Solid state	Mid IR	2.94 μm
19	Carbon dioxide	Gas	Far IR	10.6 μm

Lasers can operate continuously (continuous wave or CW) or may produce pulses of laser energy. Pulsed laser systems are often repetitively pulsed. The pulse rate or pulse repetition frequency (PRF) as well as pulse duration and peak power are extremely important in evaluating potential biological hazards. Due to damage mechanisms in biological tissue, repetitively pulsed lasers can often be more hazardous than a CW laser with the same average power. The retina is especially sensitive to laser light beams for two reasons:

1. Irradiance from a conventional source, such as a light bulb, is reduced with increasing distance from the source according to the inverse square law, i.e. the irradiance is reduced as a function of the square of the distance from the source. Since a laser beam is collimated, it does not follow the inverse square law and its irradiance for a given power output is usually far greater at a given distance than that from a conventional light source; and
2. If light from a conventional source is focused by means of a reflecting surface, as in a searchlight, the irradiance downrange of the source is greater than would be expected according to the inverse square law. However, it is not possible to collimate conventional light energy. For a given power output, a conventional light source cannot, therefore, produce a light beam which has an irradiance similar to that of a laser beam (ICAO, 2003).

In the context of air travel, the term "laser strike" refers to the attempt to shine a beam of light into the cockpit of a passenger jet aircraft, either accidentally or intentionally, by using a laser pointer as a light source. The term "laser" stands for "amplification of light by radiation-stimulated emission."

Laser light is unique from other types of light in that it contains only one hue and has a terahertz spectrum. It makes the laser beam easier to see than other types of light. Although light from other sources tends to scatter, the laser beam retains its concentration even when traversing considerable distances.

Lasers are classified into four classes:

1. Class 1
   For example, it is a laser that does not cause damage hazards in laser printers.
2. Class 2
   The radiation released is 400–700 nm, and it is recommended to use protective glasses divided into 2, namely Class 2 and Class 2 M (can be dangerous when viewed using specific optical instruments).
3. Class 3
   They are divided into classes 3R (R stands for reduced requirements) and 3B (requires supervision from officers).
4. Class 4
   It is a laser that can pose the most danger. Health problems can appear in the eyes and skin (Bargman, 2010).

Laser attacks are hazardous and have the potential to hamper pilot performance. Since the precision of the laser, when focused on the target eye, can lead to momentary loss of vision:

a. Shock and Loss of Concentration
   A pilot can lose control of the aircraft at altitudes of up to 3,700 feet (1,127 meters) due to sporadically erupting light from the cockpit, shock toward the sea from the aircraft, or both.
b. Glare and Visual Impairment
   The laser beam has the potential to block the pilot's view at an altitude of about 365 meters (4,200 feet) and reduce his visibility outside the cockpit
c. Temporary Blindness

At a distance of about 106 meters, the effect of the laser beam is comparable to that produced by a camera flash (about 350 feet). Pilots will be blind for a short time or can see, but some dark areas on the map may make it difficult for them to see what is happening (Nakagawara et al., 2007). Laser strikes on aircraft remain a serious threat to aviation safety. Intentionally aiming lasers at aircrafts poses a safety threat to pilots and violates federal law. Many high-powered lasers can incapacitate pilots flying aircraft that may be carrying hundreds of passengers. The FAA works closely with federal, state and local law enforcement agencies to pursue civil and criminal penalties against people who purposely aim a laser at an aircraft. The agency takes enforcement action against people who violate Federal Aviation Regulations by shining lasers at aircraft and can impose civil penalties of up to $11,000 per violation. The FAA has imposed civil penalties up to $30,800 against people for multiple laser incidents (FAA, 2016).

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In Indonesia, violating laws and regulations regarding using lasers, kites or drones in flight is a severe violation. By Articles 210 and 421 of Law of the Republic of Indonesia Number 1 of 2009 concerning Aviation, those who violate this law are threatened with a maximum sentence of three years in prison and a maximum fine of IDR 1 billion (Republik Indonesia, 2009), when the air traffic controller receives many reports from pilots that there are laser problems in the final approach area or the movement area near the runway, he will be more careful when carrying out his responsibilities. Air traffic controllers can even convey this information to other aircraft, making an approach or landing, which will cause the pilots of those aircraft to be more careful.

Some laser attacks can produce blinding bursts of light, which can be uncomfortable when flying; this will impair the pilot's judgment as there is a possibility of the pilot experiencing partial or total blindness. Undoubtedly, this will cause a domino effect, which will result in the landing being postponed or even cancelled altogether. Nevertheless, several incidents occurred while the author was attending On the Job Training, and all of them were related to the fact that laser attacks were present at SMB II Airport:

a. At 18.46 West Indonesia Time (WIB) on November 6 2021, the plane pilot reported a laser hazard in the area leading to the plane's cockpit. After getting information about it from the pilot's observations, the air traffic controller issues a warning about the danger. Documentation of the Report Tower incident on November 6, 2021, is in Figure 1.

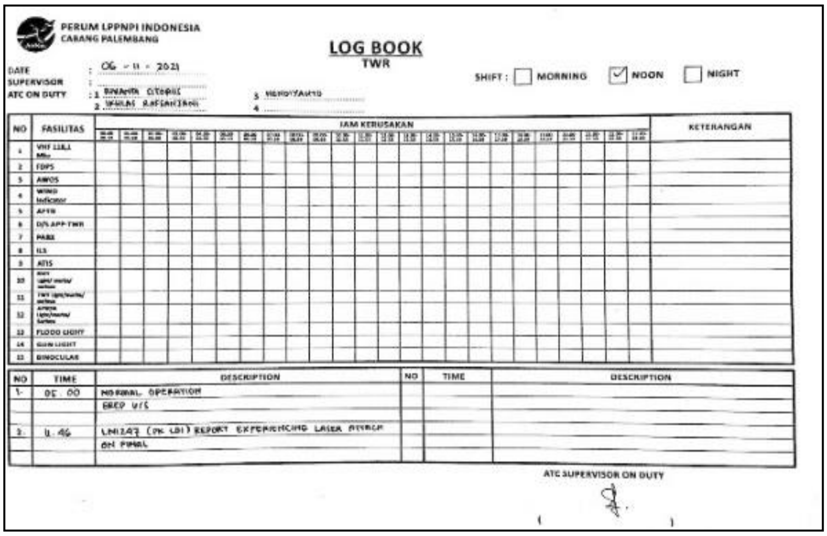
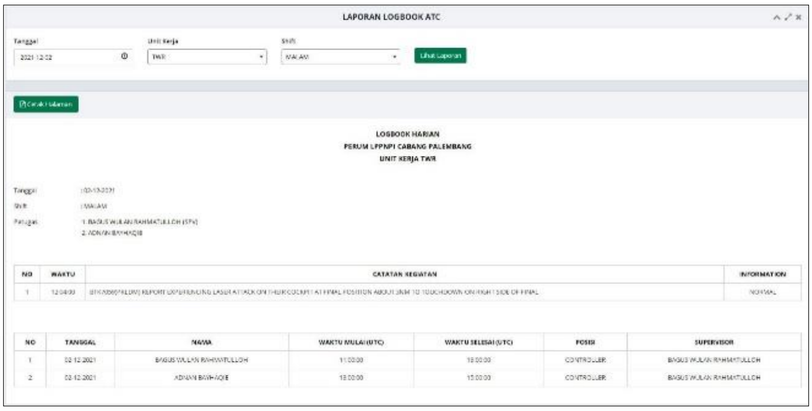


Figure 3. Log Book ATC

b. The following incident occurred on December 2 2021, at 19:04 WIB; the pilot reported a laser hazard in the final area, precisely on the final side of runway 29. Based on observations, the air traffic controller warned about the danger around the aircraft cockpit.



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We then discussed this incident with the air traffic controller, who was working at the time. The chat transcript provides access to several pieces of information, one of which is the revelation that laser attacks often occur in the final area of Runway 29. The presence of a spacious yard and playground around the airport area, as well as laser sellers, are attractive factors for people to play with lasers. At the time of the incident, the actions taken included coordinating with related parties such as Aviation Security (AVSEC) so that the person playing with the laser was immediately given a warning and coordinating with management regarding preventive follow-up so that this incident does not happen again.

Information obtained from safety stated that this incident occurred due to low public awareness and understanding of the dangers of laser attacks on aviation, especially by deliberately shooting lasers towards the cockpit. Adequate steps must be taken to prevent laser light emissions from adversely affecting flight operations (General, 2018).

The International Civil Aviation Organization (ICAO) has also taken steps to address the issue, issuing guidelines for member states on mitigating the risks of laser interference. These include recommended practices for reporting incidents, public education campaigns, and the regulation of laser devices (ICAO, 2021).

Several preventive procedures can be taken to anticipate laser attacks, namely:

1. Pre-flight procedures, namely notices to airmen (NOTAMs), must be consulted for the location and operating time of the laser activity, and alternative routes must be considered. Flight maps should be consulted for permanent laser activities (amusement parks, research facilities).
2. Procedures during the flight before entering airspace with known laser activity are: exterior lights must be turned on to assist ground observers in locating and identifying the aircraft, autopilot must be engaged, one pilot must remain on instruments to minimize possible illumination effects, and flight deck lights must turn on(ICAO, 2003).

In-flight procedures during and after laser beam illumination of the cockpit, if a pilot is exposed to a bright light suspected to be a laser beam, the following steps are recommended to reduce the risk unless the specific action would compromise flight safety;

1. Look away from the light source.
2. Shield eyes from the light source.
3. Declare visual condition to other pilots.
4. Transfer control of the aircraft to another pilot.
5. Switch over to instrument flight.
6. Engage autopilot.
7. Manoeuver or position the aircraft such that the
8. laser beam no longer illuminates the flight deck.
9. Assess visual function, e.g. by reading instruments
10. or approach charts.
11. Avoid rubbing eyes.
12. Notify air traffic control (ATC) of a suspected inflight laser beam illumination and, if necessary,
13. declare an emergency

Contracting States may be guided by the following text examples when controlling the hazards of laser beam emissions or enacting regulations in accordance with Annexes 11 and 14:

1. No person shall intentionally project, or cause to be projected, a laser beam or other directed high intensity light at an aircraft in such a manner as to create a hazard to aviation safety, damage to the aircraft or injury to its crew or passengers.
2. Any person using or planning to use lasers or other directed high-intensity lights outdoors in such a manner that the laser beam or other light beam may enter navigable airspace with sufficient power to cause an aviation hazard shall provide written notification to the competent authority.

3. No pilot-in-command shall deliberately operate an aircraft into a laser beam or other directed highintensity light beam unless flight safety is protected. This may require mutual agreement by the operator of the laser emitter or light source, the pilot-in-command and the competent authority (ICAO, 2003).

Further research on new technology for preventing laser light attacks on human eyes, specifically using unisex glasses, combines laser glasses technology (LPE) with dynamic solar filters (V-DSF). These glasses provide a solution for day and night eye protection (Aritonang & Juhana, 2018). Advancements in technology offer potential solutions to mitigate the impact of laser strikes. For instance, the development of anti-laser eyewear that pilots can wear during critical phases of flight has shown promise in reducing the effects of laser illumination (Smith & Jones, 2019). Additionally, aircraft manufacturers and researchers are exploring cockpit modifications and materials that can deflect or absorb laser beams, thereby minimizing the risk to pilots (Doe & Roe, 2020).

CONCLUSION

The conclusion obtained is that laser attacks often occur at airports, and many local people still do not understand the impact of the dangers of using lasers fired towards the cockpit. Flight safety can be achieved when all safety determinants are met; efforts can be made to reduce the risk of danger from laser attacks by the surrounding community, namely:

a. Carry out several preparatory procedures before flying and during the flight.
b. Increase the amount of outreach to the community in areas within 15 kilometres of the airport;
c. The authorities can also take strict action against people who deliberately shoot lasers at the cockpit;
d. Public awareness campaigns aimed at highlighting the dangers of laser strikes, coupled with stringent enforcement of existing laws, are crucial components of the mitigation strategy. Educating the public about the potential consequences of what may seem like a harmless act is key to preventing incidents.
e. Pilots and crewmembers should report laser incidents as soon as possible to minimize risk.

This research only provides examples of a small portion of laser attack incidents, so it is recommended that future researchers continue research and provide additional, more detailed information regarding laser attack incidents towards the cockpit.

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