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ARTIFICIAL INTELLIGENCE PERFECTING AUTONOMOUS DISTRESS LOCATOR: DEFUSING FALSE POSITIVES

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ABSTRACT

Emergency Locator Transmitters (ELTs) are devices equipped in aircraft to provide coordinates in emergency situations, although during collision with the ground the ELT is damaged preventing transmission of the signal with the coordinates, as well as when the aircraft is submerged in rivers or seas the warning signal is not transmitted. Some regions of Brazil, especially the Amazon rainforest, have communication problems with pilots to resolve questions about aircraft safety. The lack of communication linked to the activation of the ELT can trigger search and rescue missions. Thus, to respond to this challenge, we propose the application of an intelligent system, called the in-flight emergency locator transmitter (ELT-DT), which is autonomously activated during because it detects the anomalous behavior of the aircraft and already activates the transmission before it is damaged with the ground. The problem is that ELT-DT can generate false alerts, because aircraft may present some angulations considered abnormal, but this may be due to transient turbulence. Then, the method will take place in data modeling with characteristics of angles of attack that indicate that the aircraft is in a state of pre-stall, stall - when the aircraft loses support in flight -, as well as when it returns to the normal state. Previously said, it will be possible to perform the method with stall data combined with artificial intelligence techniques. The article proposes the use of Artificial Intelligence (AI) to mitigate false alerts that may trigger unnecessary searches. Based on a proof of concept (PoC) to evaluate the capacity of Artificial Intelligence (AI) to solve and manage the ELT-DT. Soon, tests will be done with AI in search of the best performance AI. The results show that AI can mitigate false alerts from ELT-DT and prevent the triggering of rescuers unnecessarily generating large expenses to public coffers.

Keywords: ELT-DT, Artificial intelligence, Autonomous distress locator, Stall, Alert.

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GENERATIVE AI USAGE STATEMENT

"This research did not use generative AI."

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1 INTRODUCTION

ELT-DT is part of Cospas-Sarsat, an international program, that provides satellite-assisted search and rescue service by providing location data of an aircraft that has made a forced landing or even an accident. The program was established jointly by the United States, the former Soviet Union, France, and Canada in 1979. The exact coordinates of the accident site represent the provision of rapid assistance, especially when human life tends to be shorter in the water, since the aircraft can fall into the high seas. In waters with a temperature of 5°C (41°F), it is estimated that it will take approximately one hour for a normally clothed individual to survive, with 50 percent probability of survival. A search time of six hours is recommended (DECEA, 2025).

Communication failures of air traffic control agencies with pilots either due to problems in the aircraft equipment or due to inhospitable regions in the Amazon rainforest coupled to the ELT activation can trigger search and rescue missions in which Air Force aircraft are displaced to the location where the ELT reported the coordinates. If an aircraft does not transmit coordinated alerts, it may be due to damage to the ELT's antenna or its own body. The damage suffered by the ELT may be related to whether the aircraft caught fire, exploded, submerged in water, or was struck with the ground at the time of impact. The ELT is not designed to withstand a serious crash, unlike flight recorders (CRV, popularly, black box) (Delcuvellerie, 2018).

The ELT-DT was developed to solve the problem of the inoperability of the ELT with the shock in the ground or with the water. The ELT-DT because it is connected with the aircraft avionics can analyze anomalous behaviors of the plane and intelligently start the automatic sending of warning signals with the position of the aircraft before the accident occurs, see Figure 1. The aircraft avionics operates relevant flight applications and system functions according to the organization and composition of the specific aircraft resource systems. Thus, the ELT-DT or the common ELT with its antennas do not transmit underwater, as well as the antenna is essential for the transmission of the warning signal and is damaged with the impact, so the importance of activation before the impact.

Figure 1: Activation of the ELT-DT during flight and the ELT after impact. Source: ICAO.

The ELT-DT arose due to air disasters with high worldwide repercussion:

(i) In 2009, Air France flight 447, which began its route from Rio de Janeiro-Galeão International Airport in Brazil to Paris-Charles de Gaul-le Airport, crashed into the Atlantic Ocean and its traditional ELT did not generate any signal. Failure of the fuselage ELT antenna in a crash prevents transmission of the signal. Furthermore, the ELT is unable to transmit underwater. Table 1 provides data that shows the search efforts, as well as the high expenses to try to find people.

Table 1: Flight Air France 447 BEA published in 2009

Search time	3 years
People on board	228
Dead	228
Dead found	154
Resources	Ships, aircraft, submarines, drones
Costs	More than 100 million dollars

(ii) In 2010, a seaplane crashed on its way back from fishing northwest of Alekna-gik, Alaska. Five of the nine people on board died and two were injured. Ted Stevens, former US Senator for Alaska, was among the fatalities, figure 2. Among the survivors is former NASA administrator Sean O'Keefe. As the plane's ELT was not activated, O'Keefe and the other survivors had to wait 12 hours for search-and-rescue teams to find them. The Search and Rescue (SAR) office has thoroughly reviewed thousands of air claims reports, conducting a comprehensive study on the non-triggering of the ELT. The investigation determined that about 58 lives were lost each year due to ELT failures (NASA, 2019).

Figure 2: ELT from the US senator's plane did not send a distress signal. Source: NASA.

Most expensive search operation in the history of aviation

(iii) In 2014, the Boeing 777, flight MH370, of the airline Malaysia Airlines disappeared 40 minutes after take-off (Епифанов, 2018). It has become one of the greatest mysteries of world aviation, the international community and the International Civil Aviation Organization (ICAO) proposed the implementation of a system that would eliminate the loss of the plane in the accident, because it is necessary to an alert device that is activated before the impact (Wan, 2021). Boeing 777 had a portable ELT, to be operated manually from the cabin, one fixed in the back of the aircraft that is triggered automatically on impact or contact with water, and two additional devices on the emergency slides. The ELTs signals from Malaysia Airlines flight 370 were never transmitted (Belzer, 2015). This case resulted in one of the largest maritime search operations as well as the most expensive. Table 2 provides information on the case of Malaysia 370.

Table 2: Flight Malaysia 370 MOT published in 2018

Search time	3 years initially, but later extended to more than 10 years
People on board	239
Dead	239
Dead found	0
Resources	Ships, aircraft
Costs	200 million Australian dollars. The HMAS Success ship from Australia alone costs 511.000 dollars per day. China's Ilyushin Il-76 plane costs 10.000 dollars per hour to stay in the air (Wardell, 2014).

If the ELT had sent the location the first responders would know what happened in a few minutes and aircraft found. Soon, the ELT-DT appears as a solution for those cases where aircraft have not been found to date. From 1 January 2025, all aircraft with a take-off mass greater than 27,000 kg for which the individual certificate of airworthiness is issued for the first time or after 1 January 2024 shall carry the ELT-DT (IATA, 2025). ICAO recommends that aircraft over 5,700 kg have a similar capacity, although these technologies only apply to newly manufactured aircraft, but there is an incentive to adapt aircraft with ELT-DT systems since they can be used to replace the common ELT (ATSB, 2018).

The Emergency Locator Transmitter for In-Flight Distress Tracking (ELT-DT) is automatically triggered when it detects abnormal aircraft behavior and generates tracking points. The ELT-DT will be activated when it detects: unusual speed, with possible excessive vertical speed or stalling condition (aerodynamic condition that occurs when the soft flow of air over the aircraft wings is interrupted, resulting in loss of lift (Delcuvellerie, 2018), see figure 3.

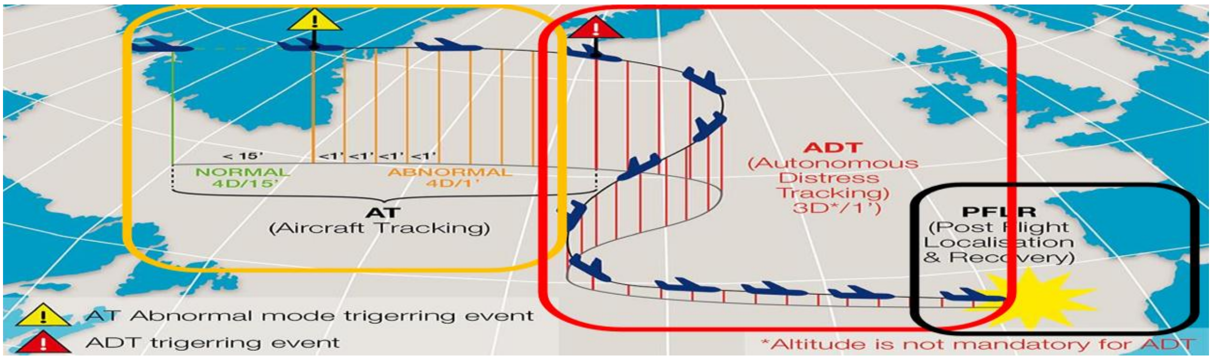

Figure 3: ELT-DT activated in flight due to abnormal aircraft behavior. Source: Eurocontrol (2020).

The problem of the ELT-DT is that the aircraft can pass through a region with severe weather formations momentarily losing support which could indicate a stall situation activating the alert of the ELT-DT. The aircraft entering the stall angle would leave the ELT-DT activated generating a position trail even as the aircraft returns to its normal flight angle. If the air traffic control center cannot contact the pilot due to communication failures, a search and rescue mission may be initiated (SAR mission).

This is a scenario where the aircraft is safe, but with the ELT-DT activated and without the possibility of talking to the pilot. Therefore, this generates false positives in which the authorities imagine that the aircraft is in danger but actually safe. The angle of attack of the aircraft may change when passing severe weather formations leading to the activation of the ELT-DT, as well as lead to thinking that the aircraft is in danger.

To solve this problem, the article aims to test artificial intelligences and find the AI that presents the best management metrics for the ELT-DT. The work is based on a proof of concept (PoC) to evaluate the capacity of Artificial Intelligence (AI) to solve and manage the ELT-DT. The contribution occurs with the AI's detection at the moment of the ELT-DT activation due to a stall and when it returns to the non-stall angle, helping to avoid unnecessary search missions with high aircraft displacement values from the Air Force. Soon, AI will be tested in search of the one that presents best performance. As soon as the aircraft leaves the danger state, the receiving center of the ELT-DT alert signal will send a no danger message to the receiving center indicating that it was a passenger problem.

2 BIBLIOGRAPHIC REVIEWS

While the primary focus of the studied is centered on just describing the concepts and applications of ELT-DT this article aims to mitigate problems of false alerts that are recurrent with traditional ELT and consequent will appear with ELT-DT. The articles about ELT-DT are few and they make approaches quoting definitions and functions extracted from official documents. The ELT-DT is a technology recently implemented in aircraft over 27 tons and it is important to minimize false alerts of the ELT-DT. The ordinary ELT presents activations as a result of going through strong turbulence, suffering a gust of wind even landed on the ground triggers the device generating a false alert.

Delcuvellerie (2018) makes a comparison between the ELT-DT (during flight) and usual ELT (after impact). Points out that the ELT-DT should provide exact location information in less than 5 seconds (to be compared with 15 seconds of the ELT). Епифанов (2018) brings prospects of implementation and advantages of the ELT-DT, as well as its development and use in Russia.

Jeong et al. (2018) address technical aspects of the operation of ELT-DT that are contained in official documents of the Cospas-Sarsat program in which the first transmission must begin within 5 seconds from the activation of the beacon. From the activation of the beacon, a total of 24 initial transmissions should be separated by fixed intervals of 5 seconds. These transmissions must be followed by 18 transmissions separated by 10 fixed seconds. After the first 300 seconds, transmissions from the ELT-DT shall continue at nominal intervals of 28.5 seconds until the end of the service life of the ELT-DT.

Wan et al. (2021) analyze the operation of the ELT-DT with the China Mission Control Center (CNMCC), focusing on the difference between the emergency locator transmitter (ELT) and the ELT (DT) and its prospects. Ji et al. (2022) study the applicability of ELT-DT for spaceflight on module reentry and locate astronauts. Ping (2023) addresses the design and research on the architecture of ELT-DT in which it is a solution to the problem of tracking aircraft in distress.

3 METHODOLOGY

The methodology consists in modeling the dataset from information of the angle of attack of the aircraft in pre-stall, stall, pre-processing data, analysis of evaluation metrics that allowed to reach the AI with the best performance, model development, comparative classification, and evaluation metrics to ensure accurate and reliable results.

3.1 Modeling of the data

The dataset for AI training and testing was constructed from the aircraft angles of attack in normal, pre-stall and stall states, according to equation (1) where α is the aircraft angle of attack (Tapolcai et al., 2017).

$$\begin{gathered} \boldsymbol{\alpha \leq 14.35^{o}} \textbf{ (normal)} \\ \boldsymbol{14.36^{o} \leq \alpha \leq 15.59^{o}} \textbf{ (pre-stall)} \\ \boldsymbol{15.6^{o} \leq \alpha \leq 19.6^{o}} \textbf{ (stall)} \end{gathered} \tag{1}$$

Stall occurs when a wing exceeds the "critical angle of attack." The angle of attack in aerodynamics is the angle between the relative wind and the wing rope line (Liu et al., 2019). The dataset is composed of four attributes:

(i) aircraft angle of attack;

(ii) time in minutes that the aircraft will remain in its respective state both to the moment it enters a stalled state and returns to normal. The ELT-DT should, for example, remain for 2 minutes still activated as a safety margin, because it may be that the aircraft returns to the alert state and does not miss the tracking plots in the 2 minutes of normal state;

(iii) altitude is an important attribute because it is related to the loss of lift of the aircraft, that is, when the aircraft begins to fall. The loss of altitude was defined by analyzing the case of the Voepass flight in 2024, which crashed - went into a flat screw - and killed 62 people falling in a residence in Vinhedo-SP. The registered aircraft PS-VPB, model ATR72-500, flew at 17,000 feet altitude equivalent to 5,666 meters altitude. Lost 17,000 feet in less than 2 minutes (Moliterno, 2024), then rounding up to 2 minutes to lose the 17 thousand feet has a loss of 141 feet per second. Therefore, as a safety margin was defined a loss of 100 feet per second to feed the dataset (table 3). In addition, an aircraft

can fly safely up to the cruising flight altitude of 42,000 feet. A simulation of the altitude loss of an A320, widely used in commercial aviation, had its altitude loss per second of 125 feet (Pandie, 2024).
(iv) the state in which the aircraft is, i.e., indicates normal, pre-stall or stall that will define the activation of the ELT-DT;
(v) lable indicates the classes of non-alert and alert. Figure 4 illustrates the angles of the aircraft coming up to the stall.

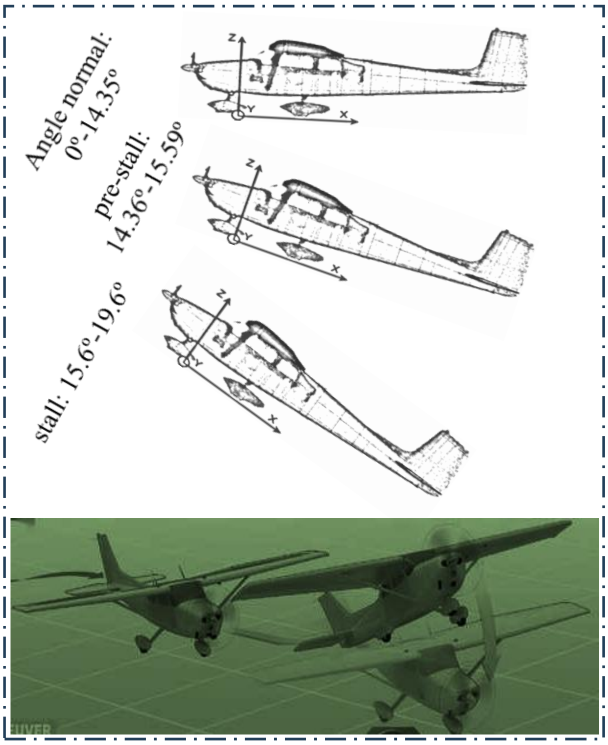

Figure 4: Angles of attack stalling. Source: adapted of AOPA (2017); Mason (2023).

The angle of attack with loss of altitude has a strong correlation for activation for the model proposed for the ELT-DT, since it is not only sufficient to be in the stalling angle, but also with loss of altitude. The aircraft at the time of take-off is with the angle of attack well accentuated and is not therefore in a stalled state. Therefore, the relevance of altitude loss to firmly define the stalling state and from this activate the ELT-DT. Table 3 illustrates some data modeled from parameters of the angles of attack of an aircraft and based on real air disaster cases.

Table 3: Modeling the dataset

ANGLES	*TIME*	*ALTITUDE*	*STATE*	*LABLE*
0º-14.35º	2 *minutes*	-	normal	non-alert
14.36º-15.59º	2 *minutes*	-	pre-stall	non-alert
15.60º-19.60º	-	*42000 to 41900* *4900 to 41800* *4800 to 41800* *41980 to 41880…*	stall	alert

The algorithm works with the activation of the ELT-DT when entering a stall by sending a warning message while the danger lasts. At the time that the aircraft leave the stall and enter the pre-stall will be sending the alert still for 2 minutes by safety margin and if direct to the state of navigability of normal will also be warning for 2 minutes so you can have traces of location as a precaution. 2 minutes was the time chosen to be sufficient for the transmission of several tracks coordinates of the aircraft, since every 5 seconds will transmit a total of 24 transmissions having in 2 minutes a total of 576 transmissions of the warning signal (Jeong et al., 2018). But after 2 minutes in normal state the alert will be deactivated by sending a no danger message to the receiving center. See an extract of the functioning of the model proposed for the ELT-DT, according to algorithm 1.

Algorithm 1: *Detection of Stall - ELT-DT*

input: *Angles attack and Time dataset → Normal → Pre-stall → Stall*
output: *detection alert message → detection non-danger message*
Capture() ← *Normal, Pre-stall, Stall;*
Detect() ← *Stall;*
if (*Detection = critical angle of stall*)
then
| *Output* ← *SendMessage(Alert_Danger)*;
while
| Time ← *as long as the danger lasts*
if (*Detection = leave the stall, pos-stall and enter: pre-stall angle → normal*)
then
| *Output* ← *Go on SendMessage (Alert_Danger)*
for *2 minutes*;
then
| *Output* ← *SendMessage(Non-danger);*
end
UpdateDetectionValues();
{Normal, Pre-stall, Stall}

3.1 Pre-processing of the data

3.1.1 Balancing of data

The data were balanced using the SpreadSubSample undersampling technique that eliminates the amount of data from the majority class (Muthumanickam et al., 2022). Figure 5 illustrates the balancing process.

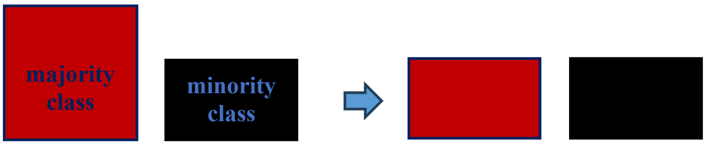

Figure 5: SpreadSubsample balancing. Source: authors.

3.1.2 Data cleaning and Randomization of the data

Subsequently, the technique ´remove_duplicates` was applied to eliminate repeated instances. Duplicate instances can bias results. Then, a randomization technique was applied to shuffle the instances. Randomization aims to avoid biases and ensure the impartiality of results. In other words, randomization is to ensure the validity of the results obtained by increasing the relevance of the conclusions obtained (Shekelyan et al., 2021).

3.1.4 Cross-validation

The data mining program Weka was used in a notebook equipped with the Windows 11 operating system, Intel® CoreTM i7 processor 4.7 GHz, 10 cores, 16 GB of RAM and 1 TB of SSD storage. Chosen the cross-validation technique with 5 k-fold, that is, it will perform 4 trainings and 1 test iterating for 5 times (Mahmoodzadeh et al., 2021). Figure 6 illustrates the operability of cross validation.

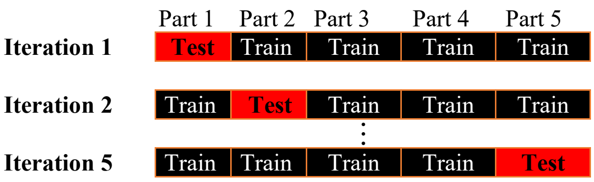

Figure 6: Cross validation. Source: authors.

3.2 Evaluation metrics for results

3.2.1 Accuracy and Kappa Statistics

Is measured within a percentage value range from 0% (low) to 100% (high). The best to achieve is a score of 80% or higher. For more sensitive cases, such as financial or medical records, recommended a score close to 100% (Microsoft, 2024). The accuracy metric is a type of evaluation statistic that evaluates how accurate a classifier is. We simply add up the samples that were correctly predicted (true positive and true negative) and divide this amount by the number of samples, see equation (2) (Rezapour et al., 2020).

$$Accuracy = \frac{Tp+Tn}{Tp+Fp+Tn+Fn} \quad (2)$$

Calculates the reliability of results between two evaluators of the same thing. A score of zero means less agreement between the two evaluators while a score of x. Can be calculated using the following where P_o is the probability of agreement and P_e is the probability of random agreement between the classifiers, equation (3) (Villavicencio et al., 2021).

$$K = \frac{Po+Pe}{1-Pe} \quad (3)$$

3.2.3 MAE and TIME

Mean Absolute Error (MAE) measures the number of errors or misclassifications in the model prediction. MAE is the average of all absolute errors; it determines how close the predicted value is to the actual value in the data set. A lower MAE means better performance. MAE can be obtained by the following formula where y_i = prediction, x_i = actual value and n = total number of instances, equation (4) (Villavicencio et al., 2021).

$$MAE = \frac{1}{n}\sum_{i=\perp}^{n}|x_i - y_i| \quad (4)$$

Time spent to build the model displays the amount of time required to train the model, so it is necessary to figure out which model will perform best (Villavicencio et al., 2021). Researchers point out that some machine learning (ML) algorithms are superior to others in the accuracy of detection to cyberattacks, but these need more training to build models. They explain that the time of model construction is an important aspect to predict the cyberattack in real life. Some ML algorithms integrated with detection systems are simple and cannot be deployed in real time due to their high model building time. A delay can compromise networks for a period before triggering any alert (Alabdulwahab et al., 2020).

4 RESULTS

What defined the AI algorithm with the best performance was the time of construction of the model, because most AI had excellent results. It is important to perform this analysis, because well all AI serves for a specific case. Some IAs such as Naive bayes, Decision and RandomForest had an assertiveness rate of 99.99% while AI Bagging had 89.77%.

The Kappa close to value 1 indicates the best result. MAE close to value 0 indicates the best performance. Crucially, Naive Bayes demonstrated a model build time of 0 seconds, which is critical for application in real-time emergency scenarios. A shorter time is crucial for deployment in real-time systems, where delays can be critical. Table 4 shows and details the comparative analysis of some AI results.

Table 4 Results

	Naive Bayes	*Decision*	*Random Forest*	*Bagging*
Accuracy	99.99%	99.99%	99.99%	89.77%
Kappa	1	1	1	0.79
MAE	0	0.2514	0.2491	0.2421
TIME (s)	0	0.03	0.15	0.11

The ability of Naive Bayes to detect and discard false alerts is vital to avoid triggering unnecessary search and rescue missions, which generate large expenses for public coffers. Especially in regions with communication problems with the pilots, such as the Amazon Rainforest. Thus, a risk for general aviation and especially for police operations in the Amazon, where Air Force missions are deployed, an assertive system is indispensable. The proposed AI system will signal the warning center to disregard a false positive alarm, but will continue to receive the coordinates for 2 minutes as a precaution, ensuring a safety margin.

5 CONCLUSIONS

The applied method proved to be efficient in the management of aircraft warning signs avoiding that false alerts are taken as true and consequently expenses avoided. The AI detecting that it is a false positive alert will warn the warning center to disregard such an alert but will continue to receive the coordinates for 2 minutes as a precaution.

For future research, the dataset of this article will be fused to the stalling speed of the aircraft. Considering that each aircraft has its stall speed specified by the manufacturer. Also, for future research will be evaluated the behavior of combat fighters that can fly up to 40 degrees before they exceed their critical angle. It is imperative to research and resolve occurrences of inadvertent ELT (Emergency Locator Transmitter) activation while on the ground. Such events are generally caused by aircraft that, even in safe conditions (on the ground), are subjected to strong wind gusts that can even tip the aircraft, culminating in the activation of the ELT and the subsequent launching of unnecessary Search and Rescue (SAR) operations. Owners even tie down their aircraft using ground anchors. This problem is further compounded by the difficulty in communicating with the pilot, which is inherent to the remote location of the aircraft.

AI Naive Bayes had a better performance in the management of the ELT-DT, because it was more assertive with the better time. The article contributes so that expensive aeronautical search and rescue missions are not started unnecessarily, as well as leaves a suggestion for the improvement of the search and rescue system from the development and implementation of ELT-DT for small aircraft that are the most disappearing in the Amazon forest due to being hidden among trees with an average height of 40 meters, but that can reach 80 meters high, as well as sink in deep rivers without the possibility of transmission of the signal of ELT, because the transmitter is damaged with impact. Soon, the development of an ELT-DT for small aircraft flying in the jungle will save many lives.

6 REFERENCES

Alabdulwahab, S., & Moon, B. (2020). Feature selection methods simultaneously improve the detection accuracy and model building time of machine learning classifiers. *Symmetry*, *12*(9), 1424. https://doi.org/10.3390/sym12091424

AOPA – Aircraft Owners and Pilots Association. (2017). Technique: Power-on stall. *AOPA*. Available at: <technique: power-on stall - aopa>. Access in: 29 set. 2025.

ATSB - Australian Transport Safety Bureau. (2018). Aircraft tracking. Available at: <https://www.atsb.gov.au/safety-issues/ae-2014-054-si-02>. Access in: 29 set. 2025.

BEA - Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile. (2009). Accident to the Airbus A330-203 registered F-GZCP operated by Air France. Available in: <https://bea.aero/en/investigation-reports/notified-events/detail/accident-to-the-airbus-a330-203-registered-f-gzcp-and-operated-by-air-france-occured-on-06-01-2009-in-the-atlantic-ocean>. Access in: 29 set. 2025.

Belzer, R., Noory, G., & Wayne, D. (2015). *Someone Is Hiding Something: What Happened to Malaysia Airlines Flight 370?*. Simon and Schuster.

DECEA – Departamento de Controle do Espaço Aéreo. (2025). Manual de Coordenação Busca e Salvamento Aeronáutico (SAR) MCA 64-3. Disponível em: <Manual de Coordenação Busca e Salvamento Aeronáutico (SAR) | Publicações DECEA>. Access in: 29 set. 2025.

Delcuvellerie, D. (2018). Tracking of aircraft in distress using the cospas-sarsat system. In *2018 SpaceOps Conference* (p. 2343). DOI: 10.2514/6.2018-2343

Епифанов, М. А. (2018). Перспективы применения и развития автоматических радиомаяков коспас! сарсат типа ELT (dt) в глобальной системе оповещения о бедствии и обеспечения безопасности полетов воздушных судов (gadss). *T-Comm-Телекоммуникации и Транспорт*, *12*(1), 32-35. DOI 10.24411/2072-8735-2018-10006

Eurocontrol - European Organization for the Safety of Air Navigation. (2020). European Global Aeronautical

Distress and Safety System (GADSS) Webinar GADSS Airbus solutions and implementation of GADSS. Available at: <https://www.eurocontrol.int/sites/default/files/2020-12/eurocontrol-gadss-webinar-2-airbus.pdf>. Access in: 29 set. 2025.

IATA - International Air Transport Association. (2025). ICAO GADSS & ADT Implementation. Available in: <https://www.iata.org/en/programs/ops-infra/techops/icao-gadss-adt-implementation/>. Access in: 29 set. 2025.

ICAO – International Civil Aviation Organization. (2022). COSPAS-SARSAT System Overview. Available at: <https://www.icao.int/NACC/Documents/Meetings/2022/GADSS/GADSS-Mod3en.pdf>. Access in: 29 set. 2025.

Jeong, G. R., Jeong, S. H., & Lim, J. G. (2018). Analysis of COSPAS-SARSAT 406 MHz Personal Locator Beacon Specification. *Journal of Advanced Navigation Technology*, *22*(6), 514-521.

Ji, X., He, Z. H., Song, X. X., Ye, J. S., & Zhang, B. M. (2022, December). Study of COSPAS-SARSAT beacon device used in chinese crewed spaceflight. In *Journal of Physics: Conference Series* (Vol. 2410, No. 1, p. 012007). IOP Publishing. doi:10.1088/1742-6596/2410/1/012007

Liu, X., Xiao, G., Wang, M., & Li, H. (2019, September). Research on Airworthiness certification of Civil aircraft based on Digital virtual flight test technology. In *2019 IEEE/AIAA 38th Digital Avionics Systems Conference (DASC)* (pp. 1-6). IEEE.

Mahmoodzadeh, A., Mohammadi, M., Ibrahim, H. H., Abdulhamid, S. N., Salim, S. G., Ali, H. F. H., & Majeed, M. K. (2021). Artificial intelligence forecasting models of uniaxial compressive strength. *Transportation Geotechnics*, *27*, 100499. https://doi.org/10.1016/j.trgeo.2020.100499

Mason, B. H., & Warren Jr, J. E. (2023). Finite Element Simulation of Three Full-Scale Crash Tests for Cessna 172 Aircraft. *Journal of Aircraft*, *60*(4), 1189-1200. https://doi.org/10.2514/1.C037125

Moliterno, D. (2024). Avião que caiu em Vinhedo (SP) perdeu 5 km de altitude em menos de 2 minutos. CNN. Available at: <https://preprod.cnnbrasil.com.br/nacional/aviao-que-caiu-em-vinhedo-sp-perdeu-5-km-de-altitude-em-menos-de-2-minutos-mostra-radar/>. Access in: 29 set. 2025.

MOT - Ministry of Transport Malaysia. (2018). The Malaysian ICAO Annex 13 Safety Investigation Team for MH370. Available in: <https://www.mot.gov.my/en/MH370%20Investigation%20Report/01-Report/MH370SafetyInvestigationReport.pdf>. Access in: 29 set. 2025.

Muthumanickam, T., & Kumar, D. V. (2022, March). Performance Analysis of a Bottleneck Layer Network in the Estimation of Cyber-Attacks. In *2022 6th International Conference on Computing Methodologies and Communication (ICCMC)* (pp. 181-187). IEEE. DOI: 10.1109/ICCMC53470.2022.9753993

NASA - National Aeronautics and Space Administration. (2019). FAA Adopts NASA Aviation Distress Beacon. Available at: <https://www.nasa.gov/aeronautics/faa-adopts-nasa-aviation-distress-beacon-recommendations/>. Access in: 29 set. 2025.

Pandie, A. R. (2024, May). Flightscape software for flight analysis of A320 flight accident data recorder to get stall speed and accident reconstruction process. In *AIP Conference Proceedings* (Vol. 3116, No. 1, p. 090006). AIP Publishing LLC.

Ping, W. (2023, December). Design and Research on the Architecture of Autonomous Distress Tracking and Emergency Locator Transmitter System for Civil Aircraft. In *2023 IEEE 11th Joint International Information Technology and Artificial Intelligence Conference (ITAIC)* (Vol. 11, pp. 594-597). IEEE.

Rezapour, M., Molan, A. M., & Ksaibati, K. (2020). Analyzing injury severity of motorcycle at-fault crashes using machine learning techniques, decision tree and logistic regression models. *International journal of transportation science and technology*, *9*(2), 89-99. https://doi.org/10.1016/j.ijtst.2019.10.002

Shekelyan, M., & Cormode, G. (2021, March). Sequential random sampling revisited: Hidden shuffle method. In *International Conference on Artificial Intelligence and Statistics* (pp. 3628-3636). PMLR.

Tapolcai, D. P., Omran, A., & Newman, B. (2017). Aircraft stall phenomenon analysis using nonlinearity index theory. *Aerospace Science and Technology*, *68*, 288-298.

Villavicencio, C. N., Macrohon, J. J. E., Inbaraj, X. A., Jeng, J. H., & Hsieh, J. G. (2021). Covid-19 prediction applying supervised machine learning algorithms with comparative analysis using weka. *Algorithms*, *14*(7), 201. https://doi.org/10.3390/a14070201

Wan, Q., Chen, Y., Ji, X., Yang, Q., & Xu, J. (2021, October). The Study of the Application of the Emergency Locator Transmitter for In-Flight Distress Tracking for China Civil Aviation Safety. In *2021 IEEE 3rd International Conference on Civil Aviation Safety and Information Technology (ICCASIT)* (pp. 111-114). IEEE.

Wardell, J. (2014). Search for MH370 to be most expensive in aviation history. Available at: <https://www.reuters.com/article/world/search-for-mh370-to-be-most-expensive-in-aviation-history-idUSBREA37095/>. Access in: 29 set. 2025.