# Automation of aviation safety events investigation

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**Abstract**

Investigation of safety events is an important task to ensure the required level of flight safety. Results of aviation events investigation help to understand factors that affect flight safety and recommend minimizing its action in the aviation system. Results of aircraft incidents and accident investigations are pointed to minimize the risk of degradation factors occurrence in the system. Aviation safety event investigation is a complicated process that is performed under local and international regulations. In the paper, we consider designing a specific software for automation of complete investigation process to minimize routine work and increase effective work-time planning. Automatic report generation based on input data helps to minimize expert involvement in the investigation process and simplify project management. The proposed software helps to easily manage and visualize investigation process. User interface is cross-platform, supported with web technology, and protected at different levels from unauthorized access.

**Keywords**

safety of aviation, air navigation, software, safety events, incidents, accidents, risk, CNS, ATM

## 1. Introduction

The safety of aviation is an important criterion of air transportation system operation. Any transportation is planned to meet the minimal requirements of safety. However, action of some degradation factors, which mostly have a rare frequency of occurrence can significantly reduce flight safety and increase probability of appearance of some dangerous flight situations [1, 2]. Any airspace use is planned to guarantee a safe air transportation connection [3]. Airspace user prepares a detailed flight plan and submits it to the aviation authority for validation and approval. Airspace usage for instrument flights can be granted only based on an approved detailed flight plan [4, 5]. At the flight-planning stage, proposed flight plan is compared with already planned air traffic to minimize the risk of mid-air collision and to provide uniform air traffic flow distribution over the network of flight routes [6].

Uncertainty of on-board positioning system [7] and dangerous factors action affect nominal flight and may lead to airplane deviation from planned 3D trajectory [8, 9]. Minimums of safe separation minimums in horizontal, vertical, and longitudinal sides specify safety perils for airplane fluctuation around a planned trajectory [4]. Reduced separation between airspace users is an important aviation event that reduces the safety of whole air transportation in particular flight-route. Valuable deviations could be a result of some dangerous factor action or violation of aviation rules of particular airspace use. Weather condition is another important factor which could significantly reduce flight safety [10].

Any event that took place while providing air transportation that affects the safety of aviation operations could be referred to aviation safety event. Commonly aviation safety events are classified into accidents and incidents [11, 12]. An aviation accident is a safety event connected with airplane

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operation, which has occurred during the time of the person present onboard, between boarding and arrival at the gate of the destination airport with one of the following cases [10]:

- passenger has a serious injury or fatalities;
- an airframe is lost or completely inaccessible;
- construction of airplane has significant damage which makes airplane unoperated for long periods of time.

Aviation incident is another safety event than aviation accidents, which is happened during the airplane performing air transportation services that significantly affect the safety of air transportation.

Result of the safety report analysis indicates some difficulties in aviation events classification and usage during investigation process [13].

Global statistic of aviation incidents for the last decade (2023-2023) is presented in Figure 1. In total 815 accidents took place (70 are fatal and 745 are non-fatal) [14]. Covid-19 reduced air traffic significantly in 2020/21 that led to a decrease total number of aviation events and improves safety indicators.

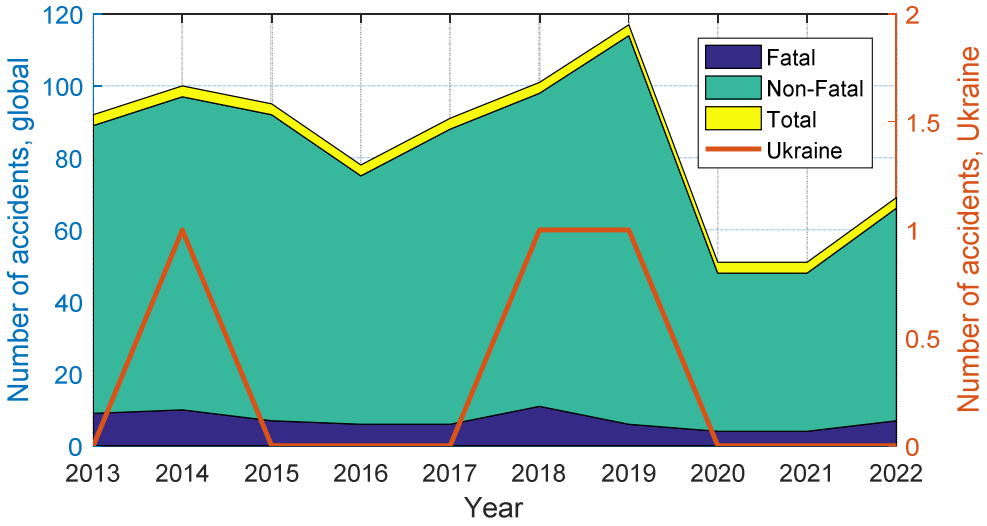


**Figure 1:** Statistic of global and local aviation accidents.

In Ukrainian airspace were only three accidents in the last decade (in 2014, 2018, and 2019). Aviation events are the subject of detailed investigation in order to identify factors that affects the safety of aviation. Results of detailed analysis of factors which are result of aviation event investigation are used for improving flight safety.

Investigation of each aviation event is performed by specific authorities under the international normative documentation [15, 16]. During the investigation process, all possible information related to the event is collected and studied accurately. Especial interest is granted to airplane trajectory which is obtained from flight data recording system (FDRS) and compared with surveillance data available in the surveillance archive of air traffic control (ATC). Ground facilities of ATC use primary and secondary radars for precise airplane location measurements. Data transferred by Automatic Dependent Surveillance-Broadcast (ADS-B) could be used. Also, maintenance data is important in the investigation process [17, 18, 19]. Analysis of trajectory data is mostly performed by a specific software [20, 21].

In our study, we provide a complete solution for the automation of aviation safety event investigation process. Investigation process is performed according to local and international regulations. This process will start with getting a request for investigation and includes multiple stages to obtain a final decision on factors that affect flight safety. Initiation of investigation process

requires preparing multiple requests for data. Automation of the whole aviation event investigation process helps to save time in routine work and increase the effectiveness of the investigation team.

## 2. Aircraft incidents and accidents investigation

Occurrence of any aviation event is a result of gaps in safety that usually occur due to multiple dangerous factors acting simultaneously [22]. Thus, the main goal of any aircraft incidents and accidents investigation is identification of dangerous factors and develop a strategy that could be realized in particular actions to improve safety levels and minimize the occurrence of dangerous events in the future [23].

The main goals of the safety event investigation process are:

- search for all causes leading to the event and propose appropriate steps to improve flight safety and avoid appearance again this dangerous event;
- identification of second-order causes that lead to the event which have not caused the event, but were connected with it;
- identify factors that helped people to survive during the dangerous factor action;
- recommendation for airplane manufacturers to minimize human injuries during airplane operation;
- prepare a final report, which includes the total summaries of the investigation and is official conclusions of the event.

International regulations indicate that country in which aviation event occur is responsible for providing an investigation process [24].

In case of an accident investigation involving large or complex aircraft, a large team of researches is usually required to investigate most effectively and expeditiously. Effective study of aviation safety event could be organized as a complete investigation project that requires effective management and a clear plan of all tasks that are required to be performed. As an example, an Investigation Management System (IMS) [25] is represented in Figure 2.

IMS is a complete investigation process that includes a sequence of activities (or investigation tasks) that have to be performed to get a decision.

In Ukraine, the National Transport Investigation Bureau (NTIB) is the only authority responsible for conducting technical investigations of aviation events, serious incidents, incidents, emergencies, damage to civilian aircraft and aircraft on the ground, and violations of the airspace utilization procedure. Technical inquiries that NTIB institutes ground on statements declared in [25, 26, 27].

Preliminary event classification, volume, and complexity, as well as the size and structure of the investigation team, are determined at a meeting of the top management of NTIB. In particular, any decisions about the investigation are made with the following factors considered:

- bodily injuries sustained as a result of an accident or incident, loss of life, and damage caused to aircraft, ground equipment services, third parties, and the environment;
- identified and potential safety issues, related to the event;
- recurrence, possibility of recurrence, probability, and severity of adverse consequences as a result of an accident or incident;
- history of aviation accidents and incidents related to this type of flight, size, and type of aircraft, operator, manufacturer, or developer;
- actual and potential deviations from aviation regulations, standards, procedures, practices and regulations of civil aviation of Ukraine in regard to flight safety and operation.

NTIB appoints a commissioner to investigate aviation safety accident, serious incident, or incident and commission members (researchers, experts). Commission consists of employees of the NTIB,

employees of the State Aviation Service of Ukraine and aviation organizations, as well as, if necessary, representatives of other interested government authorities of Ukraine (by mutual consent). Team members must be properly trained and experienced in investigating aircraft accidents and incidents.

If the investigation process does not require additional research, the investigation period should not exceed: 30 days for incidents, 6 months for serious incidents, and 12 months in case of accidents. The investigation period may be extended by the director of the NTIB based on request of the investigation commissioner.

Investigator-in-charge and members of the investigation commission must be completely objective and absolutely impartial. The commission must be formed in a way that prevents any political or other interference or pressure.

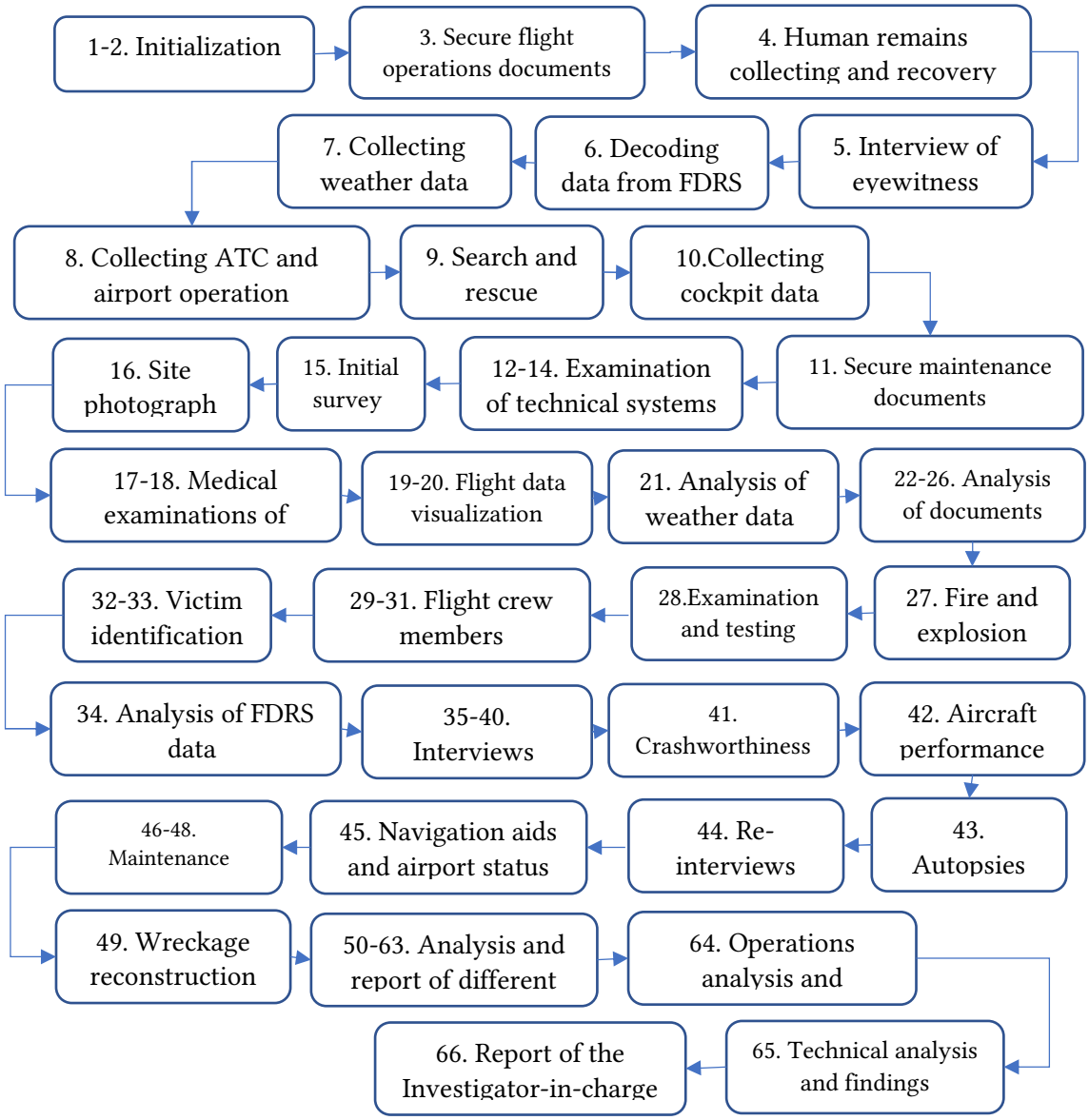


**Figure 2:** Investigation Management System.

The investigation commission must determine the primary causes of an accident and populate flight safety recommendations. Responsibility for implementation of recommendations on flight safety are assigned to the State Aviation Service of Ukraine.

To assist in the management of the investigation and the monitoring of the workload, each activity should be assigned to a group within the investigation team [26]. NTIB experts suggest that

the aviation events (AE), accidents and incidents can be named as aviation occurrence (AO) and classified by aviation occurrence class (AOC):

- ACCID. Accidents (fatal, non-fatal);
- S_INCID. Serious incidents;
- INCID. Incidents;
- OTHER. Other AE (airspace violation or undefined aviation occurrence class).

Customized investigation tasks assignment chart, grouped by AOC, is represented in Table 1.

**Table 1**
Investigation Tasks Assignment Chart, Customized by NTIB of Ukraine

| Investigation Group | ACCID (catastrophe) | ACCID | S_INCID | INCID | OTHER |
|---|---|---|---|---|---|
| Investigator-in-charge | 1,64,65,66 | – | – | – | – |
| Operations and Aircraft Performance | 3,17,31,42,50 | – | – | – | – |
| Witness | 5,19,33,44,52 | – | 5,19,44,52 | 5,19,44,52 | 5,19,44,52 |
| Meteorology | 7,21,35,54 | – | – | – | – |
| Air Traffic Services and Airports | 8,22,45,55,36 | – | – | – | – |
| Survivability | 9,23,37,46,56 | – | 9,23,37,46 | 9,23 | 9 |
| Cabin Safety | 10,24,47,57,38 | – | – | – | – |
| Medical and Pathology and Human Factor | 2,4,18,32,43,51 | 2,18,51 | 2,18,32,51 | 2,18,51 | 51 |
| Maintenance and Aircraft Records | 11,25,39,48,58 | – | – | – | – |
| Flight Recorders | 6,20,34,53 | – | – | – | – |
| Aircraft Systems | 12,26,40,59 | – | – | – | – |
| Aircraft Structures | 13,27,41,49,60 | – | 13,27,41,60 | 13,41,60 | 13,60 |
| Powerplants | 14,28,61 | – | – | 14,61 | 14,61 |
| Site Survey | 15,29,62 | – | 62 | 62 | 62 |
| Photo/Video | 16,30,63 | – | – | 63 | – |

Automation of IMS flow is described in detail in the next chapter.

## 3. Automation of investigation management process

To simplify and speed-up the investigation process, as well as reduce the human factor influence, an Automated Management System for Accidents Investigation (AMSAI) should meet the following requirements:

- automatic filtering and registration of any incoming AOC;
- scheduled notification of investigation stuff about all registered AOCs;
- noctidial access to any information related to a specific investigation;
- device usage flexibility – desktop, laptop, tablet, smartphone;
- strict security standards in connection, application and database layers;
- user's authentication, authorization and limited access to specific areas or modules;
- visualization of investigation process, the progress and duration of each IT;
- storing of investigation related files - documents, images, videos;

- fast search engine;
- automatic reports building;
- users' activities logging;
- data backup and restore;
- compliance with standards of International Civil Aviation Organization (ICAO).

The concept of AMSAI is grounded on four basic stages:

Stage 1 – Collection of all accident-related information, it's analysis, planning on the investigation scope and required resources.

Stage 2 – Investigation in accordance with specified by ICAO standard procedures depending on AOC and its consequences.

Stage 3 – Automated process of unified format report generation according to ICAO standards.

Stage 4 – Safety recommendations issue and control.

All stages provide an investigation team with all required information to support investigation process, coordination, and management.

Technical side of AMSAI is grounded on deep integration with web technology. Web technology makes possible to develop cross-platform solution which could be initiated in any personal electronic device via web-browser access. A top level of structural scheme of AMSAI is represented in Figure 3.

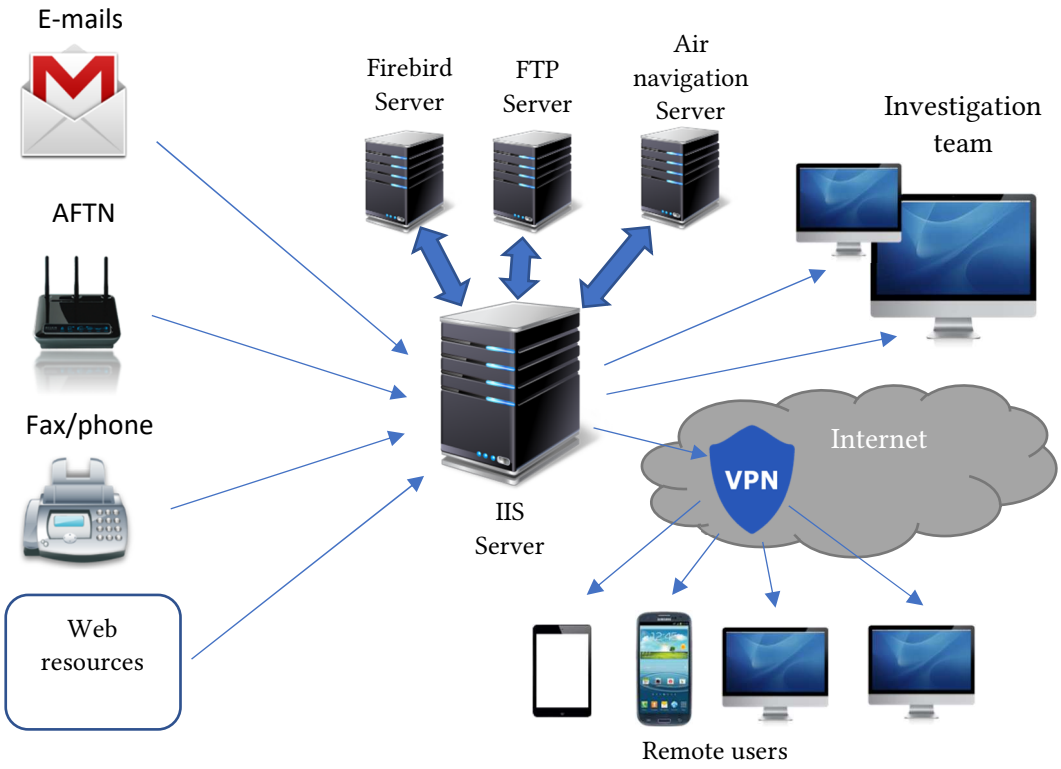


**Figure 3:** Hardware-level design of AMSAI.

At the initial stage (stage 1) AMSAI collects all the incoming data and uses a heuristic logic to detect if information is useful to the particular investigation event. AMSAI collects E-mails, faxes, automatic text generation from prerecorded calls, some web resources and messages transferred via Aeronautical Fixed Telecommunications Network (AFTN) [27–30]. If provided data is useful, information will be archived in the database (MySQL). After information is stored, the primary task is to analyze text information and determine AOC. If a source of incoming information is the web-site – AOC value is set by a person who has filled in the specific form. In case of AFTN or e-mail source, the information is represented in text format, so AMSAI applies specific semantic algorithm, which analyzes the text and determines AOC. In case of fax source – AMSAI transforms a fax

message to pdf format, runs an optical character recognition (OCR) process and applies the semantic algorithm to extracted text content. In case of phone source, or if OCR fails, AMSAI sets AOC value as empty, so the administrator is able to define AOC later manually.

Another important AMSAI's function on stage 1 is to notify all related parties about AOs. As soon as AO has been processed and stored, a notification must be created and sent to a person who is on duty at the moment. AMSAI should provide tools for setting up a duty schedule for any person within NTIB. So, the information is sent to a phone number linked to a person-on-duty by means of Short Message Service (SMS) and duplicated in a form of e-mail notification with the recipient defined by AMSAI's administrator. Common SMS notification structure is represented in Figure 4 where "NTIB Server" indicates that this message is related to AO, "Info Source" – the names of AO's sources, delimited with comma, "Status" – statistics of registered AOs. AMSAI defines the set of rules, how "Status" section should be compiled. Thus, if AOC = ACCID, a notification must be sent immediately. In this case a notification structure should be defined as described in Figure 4. However, if AOC = S_INCID or INCID or OTHER – a notification should be sent at a scheduled time and the "Status" section will include all registered AOs since the last notification has been sent. AMSAI provides tools for configuring of notifications schedule depending on AOC.

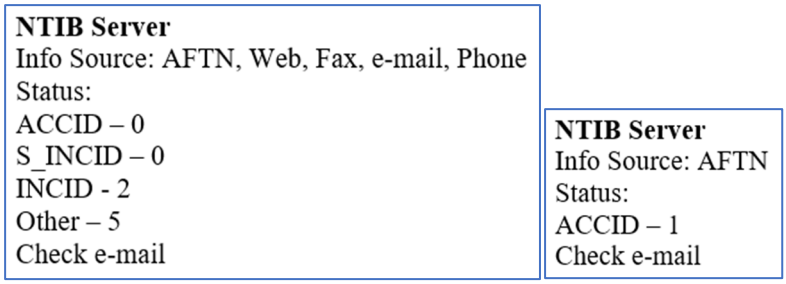


**Figure 4:** Common scheduled SMS notification structure.

An example of the list of processed AOs is represented in Figure 5. Depending on AOC administrator analyzes the AO record and creates:

- AO card – a main file that includes all investigation-specific data;
- initial messages, to be sent to ICAO and other appropriate parties.

AMSAI provide tools for automatic creation of initial messages, compliant with [16], based on the data stored in AO card.

AO card includes following data: AOC, AO date and time, country, flight stage, description of AO area, aircraft location, weather conditions, description of investigation, search and rescue operations description, AO geolocation, aircraft information (type and registration number, operator, owner, pilot-in-command, route and flight number, crew, passengers, victims), dangerous goods existence, investigation team, safety recommendations (will be filled in after investigation is complete).

Starting from this point the investigation process proceeds to Stage 2. Investigator-in-charge forms the investigation team, according to Table 1. Each investigation group work independently and acts within the assigned ITs. Each IT consists of task checklists [25]. The progress of each IT is calculated in percepts, and can be evaluated as following:

$$P_i = \frac{C_c}{C_{total}} \times 100, \tag{1}$$

where $i$ is IT number, $i \in [1, 66]$; $C_c$ is a number of completed checklists; $C_{total}$ is a total number of checklists in $IT_i$.

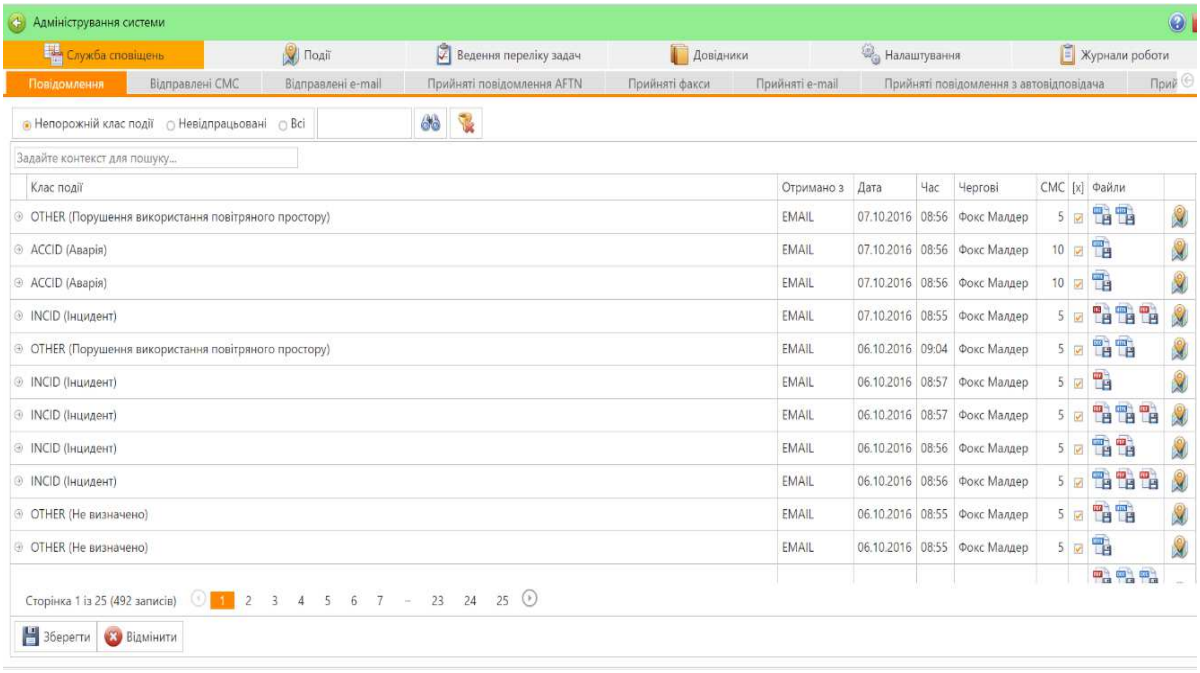


**Figure 5:** List of processed AOs.

AMSAI provides an investigator-in-charge with investigation tasks flow chart (ITFC), represented in Figure 6. ITFC allows to easily track the progress of a single IT, as well as to estimate overall investigation progress. From a perspective of an investigator, it is required that they not only check the checklists but also fill in a specific form, linked to a checklist. Checking ones without filling corresponding forms will not mark the checklist as completed, as well as it won't affect the progress of IT. Filling the forms is required for proceeding to Stage 3.

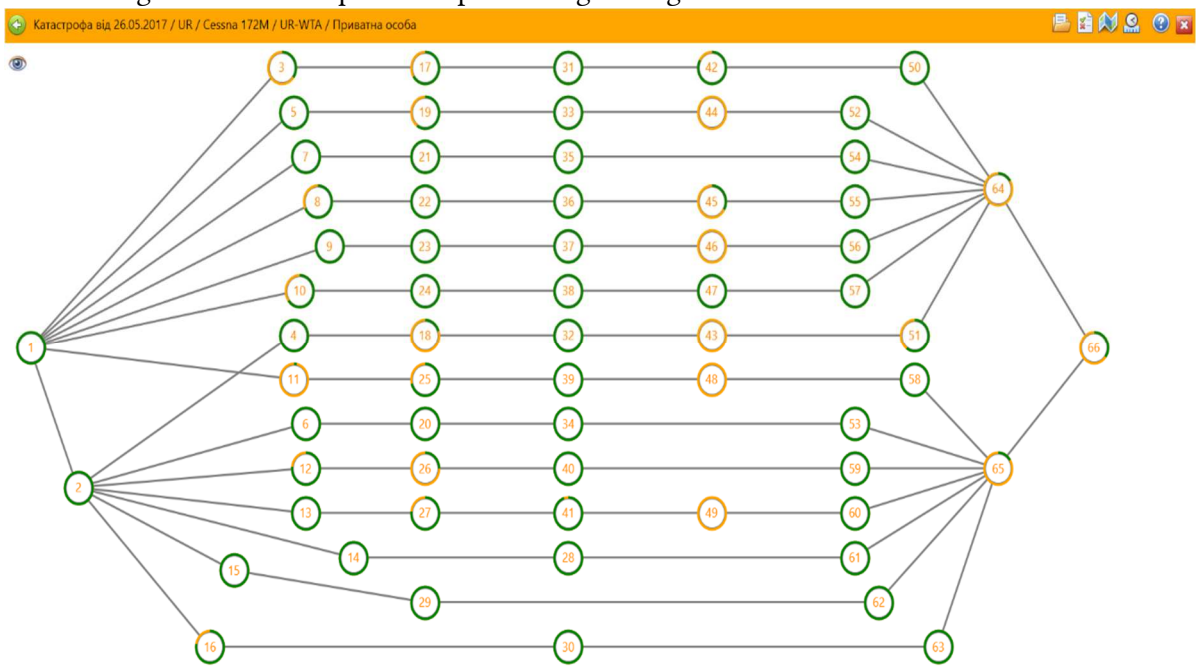


**Figure 6:** Investigation tasks flow chart.

AMSAI provides tools for automatic reports creation, based on the content, provided by experts and investigator-in-charge, during an investigation. This content includes forms, checklists, images, videos, AO card data, as represented in Figure 7.

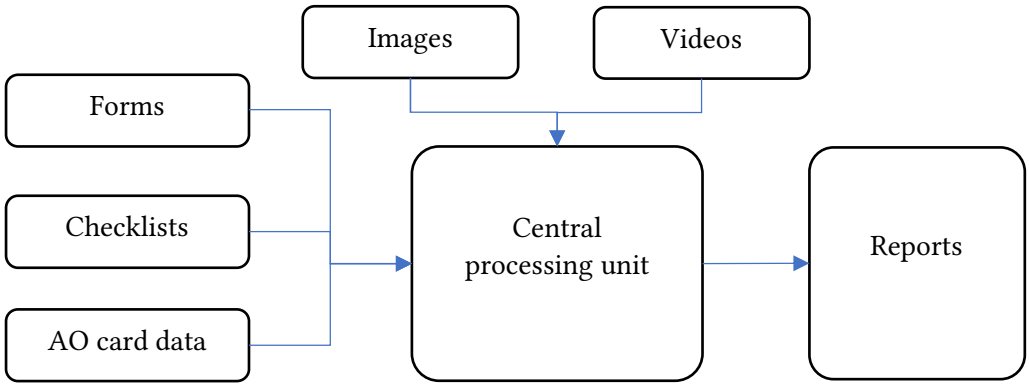


**Figure 7:** AMSAI report system.

Stage 4 starts after investigation is completed and all the factors caused an AO to happen are clarified and documented. AMSAI provides tools for creating, editing and control of safety recommendations.

## 4. Conclusions

Investigation of aviation events is an important part of the global flight safety. Results of each investigation have crucial meaning in regard to preventing accidents and incidents in the future. The main objective of aviation event investigation is to figure out all the factors that led to such an event. Additionally, an investigation can be assumed as completed only if a number of flight safety improvement recommendations have been issued. Pair of determination of destructive factors and recommendations issued compiles into a component of a common strategy of flight safety improvement. Obviously, an investigation process is a complex, nonlinear, and dynamic process. Managing such a process requires from investigator-in-charge to have strong skills and expertise. Moreover, investigation's deadlines significantly impact overall investigation process, in some cases causing mistakes in expert's conclusions. Proposed approach helps to reduce a human-factor influence on investigation, and, therefore, increases the effectiveness of aviation events investigation.

The key feature of suggested automation measures is that the majority of investigation processes can be managed within a single software information system. Strictly following ICAO standards, it provides the investigation team with exclusive tools designed for collecting and storing of evidences, accessed from any device connected to the Internet. Notification subsystem provides 24/7 awareness about incoming aviation events, notifying all related parties. Investigator-in-charge is always aware of the entire progress of investigation, as well as of each investigation task. Automatic reports building significantly reduces the time and resources needed for compiling scattered data. Several security layers prevent possible security breaches. Flight safety recommendations can be easily handled and controlled. All mentioned features allow to minimize routine work and increase the effectiveness of work-time and resource planning.

## Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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