Analysis of the Experimental Operation of the Mobile Aviation Weather Station at Svidnik Airport

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***Abstract* — The article presents the results of the assessment (identification, analysis, evaluation) of the experimental operation of the MeteoHelix IoT Pro mobile meteorological station, the Basic version, which the Faculty of Aeronautics at the Technical University of Kosice installed as part of the implementation of new didactic means of aviation meteorology as part of digital education at the faculty and for use for the benefit of the General Aviation. The article contains information on the method of installing the system, its user environment, the examination and visualization of the measured parameters of weather development, and operational modifications according to the requirements of the flying and control personnel. The article presents another concept in expanding the possibilities of the meteorological station in terms of sensory and software, inexpensive equipment of the station for the needs of general aviation, and the aviation component of the Integrated Rescue System of the Slovak Republic.**

Keywords — meteorological, station, sensors, mast, data

I. INTRODUCTION

The term "General Aviation" is not just a slang name for a certain way of flying types of aircraft used among aviators. It is a technical term with its definition according to the ICAO ANNEX 6 regulations, which states: "General Aviation are all civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire". The operations of General Aviation include flights for:

- Pilot training
- Business aviation
- Agriculture including crop spraying
- Emergency medical services, such as the transport of dangerously ill individuals and urgently needed human organs, medical equipment, and medicines
- Monitoring ground traffic movements from the air
- Civil search and rescue
- Law enforcement and firefighting
- Aerial survey work
- Aerial photography
- Newsgathering
- Sightseeing or air tours
- Flight demonstrations [1]

It is therefore a wide range of air operations, while the training flights of the students of the Faculty of Aeronautics of the Technical University in Kosice represent a significant part of the practical training in the specialty of pilots. Objective meteorological information is needed for planning, monitoring, and subsequent avoidance of dangerous weather phenomena. Until 2021, the Faculty of Aeronautics did not have a meteorological station, with which it would be possible to draw meteorological data for the needs of students' theoretical and practical training. After careful consideration of the needs and financial possibilities of the airports of General Aviation, an automatic mobile weather station from the Slovak manufacturer BARANI was purchased as part of the KEGA 051TUKE-4/2021 project. A year of its use offers the opportunity to assess the methods of sharing and the quality of the data provided, operational reliability and resistance to the effects of extreme weather conditions, the possibility of software and hardware additions to the currently provided meteorological information with other weather parameters and to perform scientific analysis and evaluation of the obtained data.

The methodology of solving the problem is based on the methods of scientific work, with an emphasis on analysis, deduction, comparison, experiment, and synthesis for the generalization of knowledge in the search and verification of the answer to the research question (RQ):

Will it be possible to visualize the measured data from the Svidnik airport, transmitted via LoRaWAN technology, on any device with a data connection?

Several researchers have addressed the issue of providing meteorological reports for the benefit of the safe and smooth operation of aviation. According to FAA statistics, weather is the cause of approximately 70 percent of the delays in the National Airspace System (NAS). In addition, the weather continues to play a significant role in many aviation accidents and incidents [2]. Weather creates numerous operational and safety hazards [3]. In terms of airliner safety, fuel economy, and pollution reduction, a timely and objective evaluation of the external situation is a major task in the assessment of weather-related hazards [4]. It is well known that, in the aviation sector, flights are strongly influenced by weather conditions, especially considering small aircraft [5]. Air carriers, but not general aviation, have long employed in-flight data to identify risks/and implement corrective measures for improved safety. Using in-flight data, aircraft (in non-instrument-rated private pilots (PPLs) ownership) operations in two potentially hazardous environments (mountains, degraded visibility) were investigated for safety practice deficiencies [6]. Other researchers addressed the issues of the aviation safety agenda in separate scientific works [7, 8].

II. METEOROLOGICAL STATION CHARACTERISTICS

After the identification of the needs of General Aviation, market analysis, and comparative analysis of individual meteorological solutions offered [9], it was decided to purchase the MeteoHelix IoT Pro automatic weather station,

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the Basic version, from the BARANI company [10]. It is an autonomous meteorological station with a backup battery, with a declared duration of 7 years from its activation, which is recharged by the solar panel shown in Fig. 1. after its

Fig. 1 Meteorological station MeteoHelix at Svidnik airport. Source: own

complete installation. The offer includes sensor equipment for a meteorological station, with measurement accuracy that follows the regulations established by the international aviation authority ICAO - International Civilian Aviation Organization. The meteorological station is independent of the line connection, which means a benefit during its installation without the need to perform excavation work for the introduction of electricity supply and data lines. Subsequent distribution of meteorological data to the AllMeteo meteorological information network via LoRaWAN technology is possible from the PC workstation.

A. Installation of a meteorological station

Before the actual installation of the station itself, it was necessary to survey the site so that the measured meteorological data would not be affected by surrounding natural or artificial obstacles. The location of the station thus meets the requirements of the World Meteorological Organization “WMO” according to the regulation "WMO No 8. Guide to Instruments and Methods of Observation" [11]. At the same time, the manufacturer guarantees the accuracy of the station's sensory equipment following the ICAO ANNEX 3 regulation [12]. The correct installation of certified meteorological sensors guarantees the objectivity and representativeness of the measured meteorological data. At the same time, however, the requirement for flight safety had to be met, as the meteorological mast represents a height obstacle that must not pose a risk to air traffic. The selection of a specific location for the meteorological measuring plot (Fig. 2.) was thus the result of the intersection of requirements for the representativeness of the measured data, flight safety, the reach of the LoRaWAN wireless network, and at the same time the specific plot had to be owned by the Svidnik airport to avoid property and legal disputes.

Fig. 2 Location of the meteorological station at Svidnik airport. Source: own

Fig. 3 Installation of a meteorological station. Source: own

The installation of the device was carried out by the authors of the article together with the generous help of the now-poor Mr. Sluka, who provided the material for the meteorological mast, the concrete foot for anchoring the mast, and auxiliary tensioning ropes (Fig. 3).

For practical reasons, the mast is foldable to facilitate the installation and maintenance of the anemometer. By cutting the mast at its base, its breakability was ensured in case of contact with an aircraft. For security reasons, the weather station was also fenced off. In the case of mowing the grass areas around the runway, damage to the station will be prevented and the fencing will prevent cyclists and pedestrians from accessing areas with tension cables, which are poorly visible against the background of the grass area and represent a potential risk. The meteorological mast is fixed to the concrete base with screws and nuts, which ensures its easy dismantling and, if necessary, relocation to another place. In this way, the mobility of the entire assembly is ensured. After moving to another location, it is enough to set up a LoRaWAN communication network via a modem, and in the station settings, the station manager enters a new location with GPS coordinates and exact altitude to convert the station's air pressure to QNH pressure - pressure converted to sea level according to the International Standard Atmosphere, which is used in aviation [12].

B. Processing and distribution of meteorological data to users

The sensory equipment of the weather station measures weather parameters according to algorithms that initiate data

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measurement according to their variability. For example, when measuring the wind, which is highly variable in time, an interval of one second is used, and subsequently the wind speed and direction are provided to the user as a floating 2 or 10-minute average. When measuring air pressure, which is not as variable in time as wind, a less demanding data measurement is used. The measured data are transmitted to the modem via LoRaWAN technology, from where they are then sent via the Internet to the workstation at the BARANI headquarters. Visualization of measured data is available on any device with a data connection (Fig. 4.).

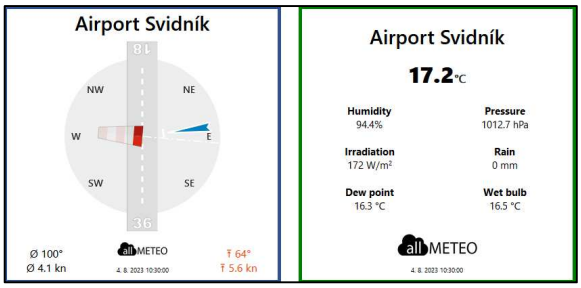

Fig. 4 Visualization of unmeasured data from Svidník airport. Source: Svidnik meteostation graphs

The way the data is visualized is the result of consultation with the manufacturer, who was extremely flexible, and suggestions from the authors of the article and the aircraft pilots were incorporated within 24 hours of the requests being made. This information is available to the general public without the need for registration and serves for operational use [12].

C. Meteorological Information Network

The measurement of weather parameters at one point provides an idea of the meteorological conditions at a specific location, which is suitable for flying with take-off and landing at the given airport and in its immediate vicinity. For the needs of flying to other airports or for obtaining an overview of the general synoptic situation, the progress of fronts, or the spatial occurrence of dangerous weather phenomena, which can lead to flight safety risks, single-point measurements are no longer sufficient. Weather monitoring is critical to identify flight safety risks like poor visibility, low clouds freezing temperatures, or thunderstorms so that pilots can avoid flying into the areas of dangerous weather occurrence or postpone the flight. For these purposes, it is necessary to have available measurements from several points, spatially distributed in such a way that the entire area of interest is covered with objective information. After purchasing the MeteoHelix IoT Pro system and its registration, the user gets access to the meteorological information network "allMeteo".

Figure 5 shows all meteorological stations of the BARANI company in Slovakia, from which all users have free meteorological information. It is necessary to point out that the sale of additional stations continuously adds to the meteorological network, and thus increases the density of coverage of Slovakia's territory by sources of objective meteorological information. The BARANI company currently provides information from four continents, while in European terms the densest network is currently in Germany. From the user application allMeteo, you can draw statistical data on

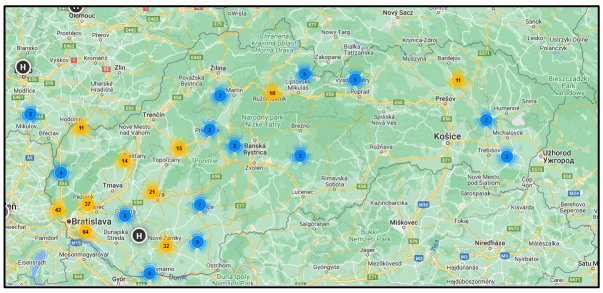

Fig. 5 Meteorological stations on the territory of Slovakia connected to the meteorological network allMeteo.Source: https://weather.allmeteo.com/#/world

measured meteorological elements changed settings and properties of the station, managed data stored on the cloud, assigned access rights to registered users, and many other options, the description of which goes beyond the scope of this article.

D. Archiving and statistical processing of measured data

Archiving of measured data is no less important than sensory measurements of weather parameters. The data archive serves to generalize the aero-climatic characteristics of the airport, monitor local deviations from the expected or monitored weather in comparison with other locations, and logically justify local influences on the creation of microclimatic peculiarities. In the case of aviation incidents, this data can be requested back from the archive, either for the needs of the investigative commission or for educational and preventive purposes.

For these purposes, the manufacturer of the meteorological station created a non-public application. After purchasing, installing, and registering the meteorological station, the user gets access to the archive of measured data and their automatic statistical processing. An archive with a 31-day history is available as soon as older data is stored in the "cloud". According to the length of the required period, not only the graph change but at the same time the data in the table below the graph, where the extremes and average values of the selected meteorological elements from 2023.07.08 to 2023.08.07 are automatically recalculated for the relevant period (Fig 6).

For a more detailed assessment of measured quantities, it is possible to request data for 7 days, 3 days, or the last 24 hours In Figure 7, there is a table below the graph in which the average values for the required days were transferred. The time interval can be shifted depending on the period that interests the user. In addition to the average values, it is possible to see the extremes of the measured element in Figures 7 and 8, in this case, it is wind gusts.

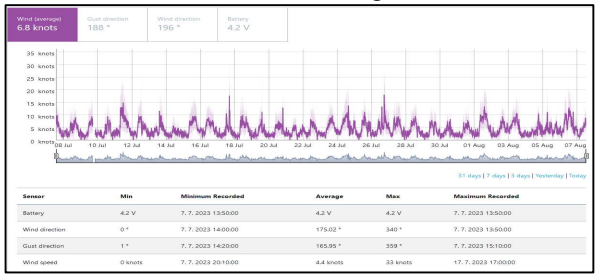

Fig. 6 A sample of the archive and statistical processing of the average wind speed at Svidník airport in 31 days. Source: Svidnik meteostation graphs

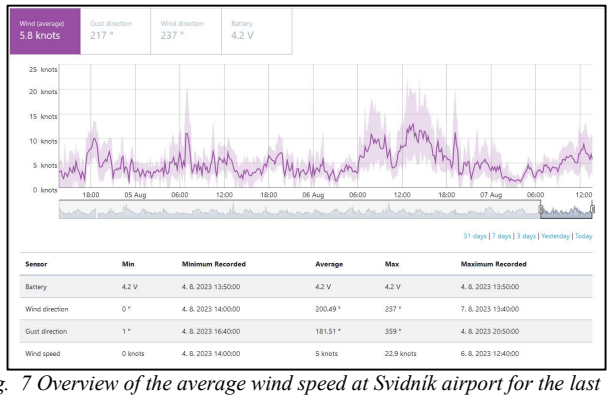

Fig. 7 Overview of the average wind speed at Svidník airport for the last three days. Source: Svidník meteostation graphs

III. RESISTANCE OF THE METEOROLOGICAL STATION TO WEATHER PHENOMENA

Each meteorological station must be able to measure meteorological elements, but at the same time, it must be resistant to extreme weather conditions, so that these extremes can be documented for further scientific processing or the warning service. In normal operating conditions, it should be reliable and almost maintenance-free. At the same time, however, it should also withstand the daily routine. The most critical weather conditions for weather stations are storms in the summer and frost formation in the cold half of the year.

Freezing precipitation in the cold half of the year means serious complications in measuring wind direction and speed. The moving parts of the anemorumbometer will stop due to the settled ice and the wind parameters may drop out even for a longer period. Currently, manufacturers solve this problem by electrically heating critical parts of wind meters. However, this requires a constant supply of electrical energy from the electrical network, as electric heating is energy-intensive and the device's batteries are not sufficient for it. The station thus loses its autonomy, its installation becomes more complicated, and the costs of purchasing the equipment and its operation increase. For the stated reasons, it was decided to purchase a measuring device without electric heating. It is generally known that in the conditions of Slovakia, there are periods with warmer and frosty days in winter, which causes melting and refreezing of settled and falling precipitation. Despite the absence of heating of the rotating parts of the anemometer, there was no data loss and the sensor was not damaged.

In the first decade of August 2023, the territory of Slovakia was affected by extraordinary storm activity with the occurrence of hail and local flash floods [13]. Storm activity was also recorded in the Svidník area. Due to the sensor capabilities of the station, these manifestations were recorded indirectly, on 2023.08.05 at 06.20 Local Time, by a drop and subsequent significant rise in air pressure, increased wind, and the beginning of precipitation (Fig. 8).

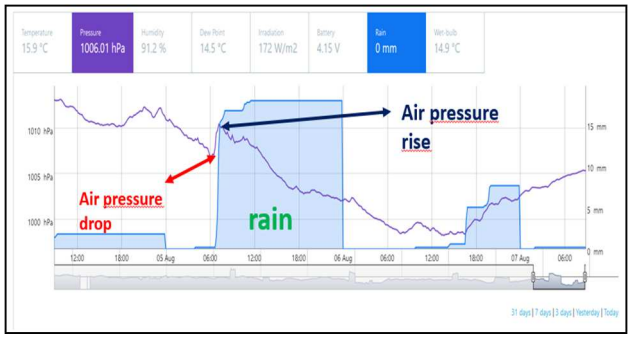

Fig. 8 The method of identifying storm activity at Svidnik Airport. Source: Svidnik meteostation graphs.

At the same time, a sudden rise in the average wind speed and its gusts was recorded (Fig. 9, bottom of the page).

Based on theoretical knowledge from the field of Aviation Meteorology in the field of storm manifestations and monitoring of weather parameters, it is possible to deduce unfavorable weather conditions in the mentioned courses of air pressure parameters and the occurrence of precipitation. The above deduction can be supported by radar and satellite images, which are publicly available on the official website of the Slovak Hydrometeorological Institute [14,15].

The timeline of the graphs in Fig. 6 and Fig. 7 shows that the meteorological station recorded these phenomena following its sensory equipment and continued to work without damage.

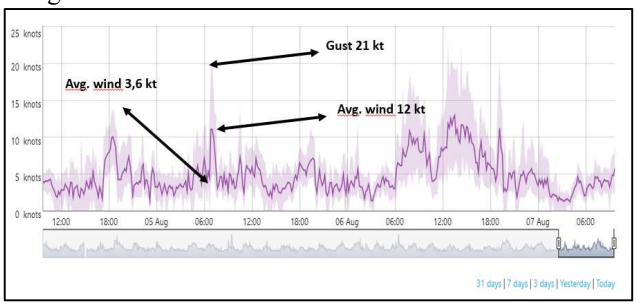

Fig. 9 The method of identifying storm activity at Svidnik Airport. Source: Svidnik meteostation graphs

IV. FUTURE POSSIBILITIES OF SYSTEM EXPANSION

The types of meteorological data provided by the evaluated meteorological station are limited by the type of its sensory equipment. Although it is possible to supplement the station with other meteorological instruments such as a weather detector, measuring visibility, or a ceilometer via connection via RS232, which is unified in the conditions of meteorological stations, these instruments, however, cost several times more than the entire station. In general aviation terms, this would be an unrealistic cost. Alternative methods of weather detection using camera systems are considered (Fig. 10).

With the help of camera systems, after supplementing the background of the image with landmarks, their distance, azimuth, and altitude, it is possible to determine the visibility, the height of the lower cloud base and its type, and also determine the occurrence of dangerous weather phenomena not only at the airport itself but also in its immediate surroundings.

Cooperation with BARANI did not end after the purchase of their system but continues. In cooperation with our faculty,

Fig. 10 An alternative to visibility measurement and weather detection. Source: own

a software METAR generator is currently being created. The purpose of the entire collaboration is to create a software tool that would automatically create a METAR report, which is a basic aviation meteorological report. After consultations with the flying staff and ATC workers from the international airport in Košice, it was discovered that the METAR report is perceived by air traffic participants as clear and comprehensible, and quickly understood.

V. CONCLUSION

The MeteoHelix IoT Pro meteorological station is small, mobile, and inexpensive, with the possibility of operational deployment in places where the situation requires it. In the event of flash floods or emergencies, it can be moved relatively quickly according to the needs and deployment of the civil defense components or the aviation component of the integrated rescue system. Rescue helicopters, which by the nature of their aerial deployment correspond to the way of flying of general aviation, can thus have objective meteorological data at their disposal, which means a significant contribution to "Situational Awareness". The mobility of the equipment means saving money for the establishment of a permanent and dense additional meteorological network on the territory of Slovakia. Thanks to the possibility of operational deployment in affected areas, the need to purchase a large number of measuring systems is not so significant. The system can be supplemented with other meteorological devices, and the user environment is constantly supplemented and developed according to the needs and consultations with the aviation personnel and with the staff of the flight training department of the Faculty of Aeronautics of the Technical University in Kosice.

Measured data is available to the general public via mobile access via a widget link. After registration and its approval, the archive and statistical processing of measured data is available to students of the Faculty of Aeronautics, teaching staff, and pilots. The archive of measured data finds its application as a digital supplement to theoretical teaching for a better understanding of the correlation between meteorological elements and meteorological phenomena in the real atmosphere.

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