

Development of a Web-Based Radar Monitoring and Failure Analysis System Integrated with the TopSky ATS

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Abstract

Radar is a crucial component of the Air Traffic Services system, supporting Air Traffic Controllers in monitoring aircraft movements and maintaining flight safety. At Airnav Indonesia Makassar Air Traffic Service Centre (MATSC) Branch, the radar disturbance recording process is still done manually, potentially leading to recording errors, reporting delays, and inefficiencies in technical evaluation. This study aims to develop a web-based radar disturbance monitoring and analysis system integrated with TopSky ATS that automatically detects, records, and visualises radar disturbances. The system is designed to recognise changes in radar status, calculate failure duration, record the number of disturbance events, and present this information in tables and dashboards in real time. Radar log data is obtained from the Control Work Position (CWP37) device via the TopSky Event Log, then parsed using the ASTERIX protocol categories 34 and 48, and stored in a MySQL database. The system was developed using the Waterfall model, while system evaluation was conducted through black-box testing and User Acceptance Testing. The results show that the system can accurately detect and display radar disturbance information in real time. The UAT, involving 10 technicians, demonstrated a user acceptance rate of 93.2%, categorised as very good. These findings demonstrate that the developed system can improve efficiency, accuracy, and timeliness in radar monitoring and support data-driven technical evaluations in air traffic services operations.

Keywords: Radar Surveillance; ATS Topsy; Web-Based Monitoring; Event Log; Air Traffic Safety.

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Introduction

Air transportation is a mode of transportation that demands a very high level of safety, punctuality, and operational reliability. In modern aviation systems, air traffic control relies not only on communication between pilots and air traffic controllers but also on various surveillance technologies that provide accurate, continuous aircraft position information. One technology that plays a crucial role in air traffic control systems is radar. Radar technology allows Air Traffic Controllers (ATC) to monitor aircraft movements in real time, thereby anticipating potential conflicts and managing air traffic more safely and efficiently (Farhadmanesh et al., 2025; Khawaja et al., 2025; Ponte & Farina, 2024; Schmölter et al., 2025).

In principle, radar works by emitting electromagnetic waves toward objects within its surveillance area. When these waves hit the object, some of the energy is reflected to the radar antenna, where the system processes it to determine the object's position, distance, and direction. In the aviation context, radar is used not only to detect the presence of aircraft but also to obtain additional information, such as altitude and aircraft identity, through the aircraft's onboard transponder system (Sumari et al., 2023, 2025; Yu et al., 2025). Integration between primary and secondary radars enables the air traffic control system to provide more complete and accurate information to ATC officers in supporting operational decision-making (Chi et al., 2023; Pérez-Castán et al., 2026; Ponte & Farina, 2024).

Developments in aviation navigation technology have encouraged the integration of radar systems with various computer-based data processing and air traffic management systems. One widely used system in air traffic management is the TopSky Air Traffic Services (ATS), which serves as a platform for processing and visualising radar data. This system allows ATC officers to obtain a comprehensive picture of the air situation through an Air Situation Display

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(ASD), which integrates radar data from multiple sites within a single surveillance system (Bestugin et al., 2020; Pérez-Castán et al., 2026; Schmidt et al., 2024).

In Indonesia, air navigation services are managed by the Indonesian Aviation Navigation Service Provider (Ainav Indonesia). This organisation is responsible for providing safe and efficient air navigation services throughout Indonesian airspace. One of the strategic air traffic control centres is the Makassar Air Traffic Service Centre (MATSC), which manages the air surveillance area in the Makassar Flight Information Region (FIR). This region covers most of eastern Indonesia and the middle, so the reliability of the radar system is a very important factor in ensuring the safety and smooth operation of flights in the region (Amrin et al., 2025; Saadah & Cahyadi, 2025; Silalahi & Sutanto, 2026).

Radar sites across various regions provide surveillance data, which the ATS system then processes to produce a comprehensive picture of the air situation. This information serves as the basis for ATC personnel to regulate aircraft spacing and flight paths, as well as handling emergencies during flight operations (Almeida et al., 2025; Chang, 2025; Weber et al., 2025). Therefore, the radar system's reliability must always be maintained so that the information received by ATC officers remains accurate and continuously available (Aliyev & Isgandarov, 2025; Chi et al., 2023; Isgandarov & Aliyev, 2024).

However, in operational practice, radar systems are not completely free from interference. Radar interference can be caused by various factors, such as hardware failure, communication network disruption, electromagnetic interference, and data processing system failure (Fei et al., 2025; Malik & Rao, 2025). Such interference can cause a temporary loss of radar data or even a failure of the radar system to detect aircraft, ultimately affecting the quality of air traffic control services and increasing flight safety risks (Aliyev & Isgandarov, 2025; Konopka & Rzucidło, 2025). In daily operations, technicians in the Communication, Navigation, Surveillance, and Data Processing (CNSD) unit monitor the radar system's condition. This monitoring aims to ensure that all radar sites within the surveillance area are operating properly and providing accurate data to the ATS system. When radar interference occurs, technicians must immediately identify the source and take corrective action to restore the radar system to normal operation.

One of the problems that frequently arises in radar monitoring is the manual method of recording radar disturbances. In some operational environments, including at the Ainav Indonesia MATSC Branch, radar disturbance recording is still performed manually, with technicians recording the disturbance's time of occurrence and duration. This manual recording method has several limitations, including susceptibility to human error, delays in data recording, and difficulties in conducting historical analysis of previous radar disturbances (Khawaja et al., 2025; Krauss et al., 2024; Seifizarei et al., 2025). Furthermore, manual recording makes it difficult for technicians to evaluate radar performance over time. To identify radar interference patterns, technicians must collect and process data scattered across various manual records. This process is not only time-consuming but also potentially produces inconsistent data because it relies on human accuracy in recording radar interference information.

Several previous studies have shown that information technology-based monitoring systems can help overcome problems associated with manual recording of operational data. Web-based monitoring systems allow for the automatic collection and display of operational data, making it easier for users to monitor system conditions in real time. (Gorden & Oluwaseun, 2025; Secreto et al., 2025; WNW et al., 2025) Developing a web-based monitoring system for evaluation and oversight activities has been proven to increase data collection efficiency and accelerate operational decision-making. Other research has also shown that automated recording systems can improve operational data accuracy and reduce operator workload in monitoring the system. (García et al., 2023; Wang et al., 2024) shows that using an automatic recording system can increase the effectiveness of system monitoring compared to manual recording methods.

In addition, several studies have also developed web-based systems to support radar monitoring. (Papazoglou et al., 2024) developing a web-based decision support system for remote weather radar maintenance by leveraging data analytics and artificial intelligence to detect potential radar failures. Other research (Patel et al., 2025; Zhan et al., 2025) proposes a web-based weather radar data visualisation system that allows users to monitor radar conditions in near real time using WebGIS technology. In the context of radar surveillance on ATS systems (Aurina et al., 2023; Binetti et al., 2022; Terrill et al., 2006; Zhan et al., 2025), developing a web-based radar status monitoring application integrated with the TopSky ATS at Ainav Indonesia's MATSC Branch. The research demonstrated that radar log data from the TopSky system can be utilised to monitor radar status in real time. However, the research remains limited to radar status

monitoring and has not integrated radar failure-duration analysis, automatic recording of disturbance-event counts, and historical data visualisation to provide a more comprehensive evaluation of radar performance.

Based on a review of previous research, it can be concluded that web-based monitoring systems have significant potential to improve the effectiveness of radar system monitoring. However, the implementation of radar monitoring systems that are directly integrated with ATS systems and capable of comprehensive analysis of radar interference remains relatively limited. Therefore, it is necessary to develop a system that not only displays radar status in real time but also systematically analyses radar interference data based on operational log data. This research aims to develop a web-based radar interference monitoring and analysis system integrated with TopSky ATS at Airnav Indonesia Makassar Air Traffic Service Centre (MATSC) Branch. The developed system utilises radar log data obtained from the Control Work Position (CWP37) device via the TopSky Event Log application, and then processes it using the ASTERIX protocol categories 34 and 48, which are radar data communication standards in aviation surveillance systems.

The main contribution of this research is the development of a radar monitoring system that automatically detects changes in radar status using operational log data, calculates the duration of radar failures, and records the number of disruption events at each radar site. Furthermore, the developed system provides a statistical dashboard and monitoring tables for radar disruption data, enabling technicians to perform radar performance analysis more effectively. Thus, this system is expected to improve the efficiency of the radar monitoring process and support data-driven technical evaluation in radar infrastructure management.

Method

Research Design

This research uses a systems engineering approach to develop a web-based radar interference monitoring and analysis system integrated with the TopSky ATS at Airnav Indonesia's Makassar Air Traffic Service Centre (MATSC) branch. This approach was chosen because the research focuses on the design, implementation, and evaluation of a software system that automatically processes radar log data to produce real-time radar interference monitoring information. The system development process was carried out using the Waterfall model, which consists of the stages of requirements analysis, system design, software implementation, system testing, and system deployment. The Waterfall model was used because it provides a systematic, documented, and appropriate development flow for system development whose functional requirements have been defined from the start (Arandia et al., 2023; Meneses & Varajão, 2022).

The research phase began with identifying problems in the radar disturbance recording process, which was still performed manually by technicians. Next, a system requirements analysis was conducted to determine the specifications of a monitoring application capable of detecting changes in radar status, recording disturbance times, calculating failure durations, and displaying radar disturbance data in tables and dashboards. The next phase was designing the system architecture and implementing a web-based application. After the system was developed, functional testing and user evaluation were conducted to ensure it met operational requirements. The research phase flow and system architecture are shown in Figure 1.

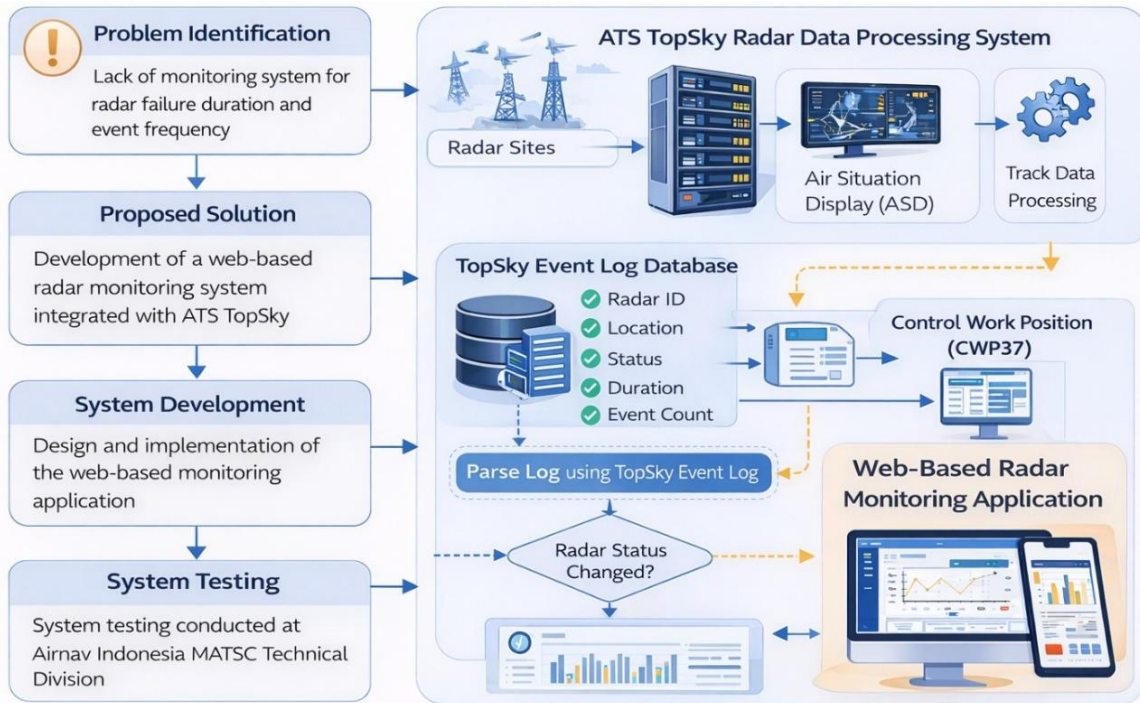


Figure 1. Research stage flow and radar monitoring system architecture

System Architecture

The developed radar monitoring system integrates radar log data from TopSky ATS with a web-based monitoring application. Radar data from various radar sites within the Makassar Flight Information Region (FIR) is received through a radar splitter and processed by the TopSky ATS system. This system displays air situation information to Air Traffic Controllers (ATC) via an Air Situation Display (ASD). In addition to supporting ATC operations, TopSky ATS also generates log files that record various system events, including changes in radar status. These log files are generated by the Control Work Position (CWP37) device, which functions as a technical supervisor workstation. The radar log data is then processed using the TopSky Event Log application to parse it, forwarding only radar status information to the monitoring system. The parsed data is stored in a MySQL database as historical radar disruption data. The web-based monitoring application then retrieves this data to display radar status information, disruption duration, number of failure events, and real-time radar statistical visualisations to users.

Data Source and Dataset

The data used in this study is radar log data obtained from the TopSky Event Log on the CWP37 device at Airnav Indonesia MATSC Branch. The log data contains radar operational status information received from various radar sites within the Makassar FIR surveillance area. Data retrieval was performed by accessing the radar log file via a PuTTY terminal connected to the TopSky ATS system. The analysed dataset consists of the following main attributes: radar site name, radar location, radar status, time of interference occurrence, radar recovery time, interference duration, and number of radar failure events. The data is stored in a MySQL database so that it can be processed and displayed again by the radar monitoring application. The radar data parsing process uses the ASTERIX protocol categories 34 and 48, which are standards for radar data exchange in aviation surveillance systems (de Riberolles et al., 2022; Vaarandi et al., 2025).

Data Processing

Radar data processing is performed using a radar status-change detection algorithm based on log data from the TopSky ATS. The system reads each radar log event and identifies any changes in radar status. When the system detects a

change in radar status from OK to FAILED, the system automatically records the initial time of the radar disruption. Furthermore, when the radar status changes back from FAILED to OK, the system records the radar recovery time. The duration of the radar disruption is calculated based on the time difference between the two events. In addition to calculating the duration of the disruption, the system records the number of radar failure events at each radar site and stores them in a database. With this mechanism, the system can automatically record a history of radar disruptions without requiring technicians to do so manually. The radar disruption detection process flow is shown in Figure 2.

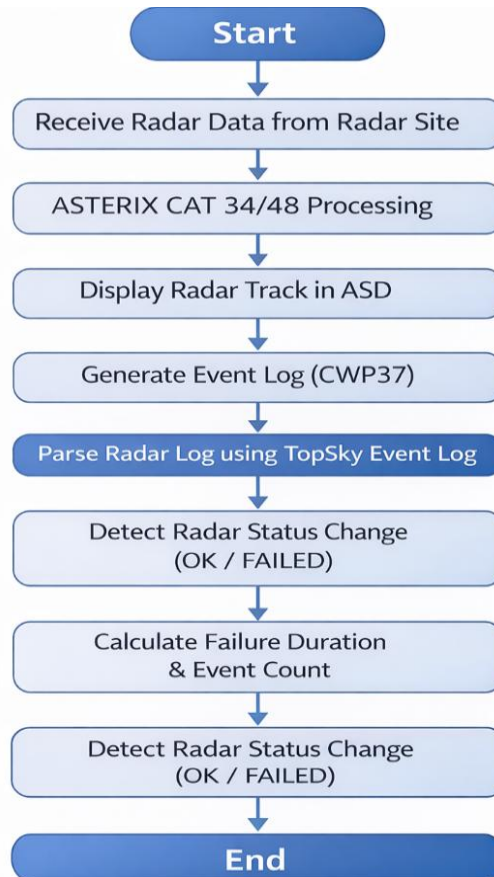


Figure 2. Flow of the disturbance detection process

System Evaluation

System evaluation is conducted to ensure that the developed radar monitoring application functions as required and is acceptable to users. System testing is conducted in two stages: Black Box Testing and User Acceptance Testing (UAT). Black Box Testing is used to evaluate the system's main functions based on the suitability of the input, processing, and output without reviewing the program code's internal structure (Aghababaeyan et al., 2023; Skalka & Drlík, 2023). This testing includes radar status change detection, fault time recording, failure duration calculation, event count updates, and data display in tables and dashboards.

In addition, user evaluation was conducted using a User Acceptance Test (UAT) involving 10 technicians from the Indonesian Airnav Engineering Service, MATSC Branch. The UAT was conducted to assess user acceptance of the system across three main aspects: usability, information quality, and user interface quality. The evaluation instrument consisted of 12 statements, each rated on a 1–5 Likert scale. The evaluation results were then converted into percentages to determine the level of user acceptance. This evaluation was used to determine whether the developed system met the operational needs of technicians and was suitable for use in a real work environment.

Results and Discussion

Result

System Functional Testing

After the system design and implementation process is complete, the next stage is functional testing to ensure that all application functions run according to the designed specifications. Testing is conducted using the Black Box Testing method, a software testing approach that focuses on evaluating system functions based on inputs and outputs without considering the program's internal structure (Hellhake et al., 2022; Skalka & Drlík, 2023). Testing was conducted at 24 radar sites within the Makassar Air Traffic Service Centre (MATSC) FIR area. Each radar site was tested by simulating changes in radar status from normal (OK) to faulty (FAILED) and from faulty to normal (OK).

This testing aimed to ensure that the system could automatically detect changes in radar status, record fault event times, calculate failure durations from timestamps, and accurately update the number of radar failure events in the database. Test results showed that all key system functions performed well. The radar monitoring system successfully identified changes in radar status, calculated outage durations, updated the count of failure events, and displayed outage information in real time via the monitoring dashboard. A summary of the functional test results is shown in Table 1.

Table 1. Black Box Testing Results

Testing Scenario	Expected results	Status
Access the Radar Table menu	Displays radar information, including location, status, date, time, duration, and events.	Succeed
Change the radar status to FAILED	Updated the radar status and increased the number of failure events	Succeed
Radar status changes to OK	Updates radar status and calculates disturbance duration	Succeed
Radar dashboard view	Displays radar condition statistics in real-time	Succeed
Storing fault data in the database	Stores status data, interruption time, duration, and number of events.	Succeed

Based on the test results, the developed radar monitoring system has met the main functional requirements and can automatically and accurately monitor radar interference.

User Acceptance Test (UAT)

In addition to functional testing, a User Acceptance Test (UAT) was conducted to assess user acceptance of the developed radar monitoring application. The UAT involved 10 technicians from the Indonesian Airnav Engineering Service, MATSC Branch, who have experience in managing radar facilities and aviation surveillance systems. The evaluation instrument consisted of 12 statements covering three main aspects: usability, information quality, and user interface quality. The evaluation results showed that the radar monitoring application achieved an excellent level of user acceptance with an average score of 93.2%. Details of the evaluation results are shown in Table 2.

Table 2. User Acceptance Test Results

Aspect	Average Score
Usability	94.3%
Information Quality	90.6%
User Interface Quality	94.4%
Average	93.2%

These results indicate that the developed system offers high ease of use, provides relevant and accurate information, and features an interface that supports effective user interaction in radar monitoring activities.

Radar Monitoring Dashboard

The results of the system implementation are visible in the application interface, which is designed to make it easier for users to monitor radar conditions in real time. The main application interface, shown in Figure 3, displays the radar statistics dashboard.



Figure 3. Radar Monitoring Dashboard

This dashboard presents key information on radar conditions in the MATSC FIR area, including the number of radar sites with FAILED status, the number with OFF status, the radar site with the longest interference duration, and the radar site with the highest number of failure events. This information is presented as statistical visualisations to make it easier for users to understand the overall radar condition. In addition, the dashboard displays a graph of radar failures at each radar site over a specified period, enabling technicians to identify sites with high interference.

Radar Table Interface

In addition to the statistics dashboard, the radar monitoring system also provides a Radar Table feature that displays more detailed radar information in tabular form. This display is shown in Figure 4.

The table interface includes filters for 'Enabled', 'Newest', 'Coordinates', 'All', and 'Conficit', with a 03.2% success rate and 3 items. Search and sort options are available. The table lists radar sites with their current status, location, last update time, and failure duration.

Radat Name	Status	Location	Last Update	Failure Duration
Kendari	FAILED	Manado	2024-04-24 15:37	2h 15m 23s 1
Pangkalan Bun	OK	Manado	2024-04-24 15:34	3h 20m 45s 1
Testing	OK	Pangkalan Bun	2024-04-24 15.34	1
Manado	OK	Kendari	2024-04-24 15.03	2h 20m 45s 5
Manado	OK	Kendari	2024-04-24 15.03	0h 45m 32s 2
Manado	OK	Pangkalan Bun	2024-04-24 15:03	2

Figure 4. Radar Table Interface

The Radar Table menu displays data from 24 radar sites connected to the TopSky ATS in eastern and central Indonesia. This table uses the DataTables library, which allows users to search, sort columns, and navigate through pagination. The displayed information includes the radar site name, radar location, radar status, status update time, duration of the radar disruption, and the number of radar failure events. Radar status is visualised using colour indicators, namely red for FAILED and green for OK, so users can quickly identify radar conditions.

Discussion

The results of the study indicate that the developed web-based radar monitoring system improves the effectiveness of radar status monitoring compared to the manual recording method previously used by technicians at the Airnav Indonesia MATSC Branch. This system works by automatically detecting changes in radar status through the analysis of log data generated by ATS TopSky. Through this mechanism, changes in radar status from OK to FAILED and from FAILED to OK can be recorded automatically, enabling the system to accurately calculate the duration of radar failure based on the time difference (timestamp) between events. This finding strengthens the results of previous studies showing that automating operational data recording can improve user efficiency and reduce the risk of manual recording errors (García et al., 2023; Wang et al., 2024). In the context of this research, this automation not only speeds up the radar monitoring process but also produces a more structured and easily analysed radar disturbance history.

The developed system utilises radar log data from the Control Work Position (CWP37) device, processed through the TopSky Event Log application. Utilising ASTERIX Category 34 and 48 protocols allows the system to parse radar data consistently and is compatible with modern aviation surveillance systems (Longo et al., 2023; Vaarandi et al., 2025). Thus, the system not only functions as a monitoring tool but also as a means of analysing radar interference data to support the technical evaluation of radar facilities. The results of Black Box Testing indicate that all main functions of the system run as required. The system successfully detects changes in radar status, records the interference time, calculates the failure duration, updates the event count, and displays radar interference data on the dashboard and monitoring tables. These results indicate that the system has a high level of reliability in performing its operational functions.

In terms of user acceptance, the UAT result of 93.2% indicates that technicians received the system very well. The usability score of 94.3% indicates that the system interface is easy to understand and use. In comparison, the information quality score of 90.6% indicates that the information presented is considered relevant, accurate, and timely. Meanwhile, the user interface quality score of 94.4% indicates that the system's visual design supports user interaction effectively. These findings align with usability engineering principles that emphasise the importance of ease of use and information quality in the successful implementation of information systems (Amannah, 2024; Lu et al., 2023). Compared with previous research by (Fei et al., 2025; Yan & Roberts, 2025) which focuses on real-time radar status monitoring, this research provides further contributions by integrating radar interference analysis functions, including calculating failure duration, automatically recording the number of interference events, and presenting historical radar visualisations. Thus, this research not only develops a radar status-monitoring system but also provides a means for data-driven radar performance evaluation.

However, this research still has several limitations. The developed system still relies on the availability and integrity of log data generated by the TopSky ATS. Furthermore, the system is not yet equipped with predictive analytics features to predict potential radar disruptions before failure occurs. Therefore, further research can develop this system by adding a machine learning approach to support predictive maintenance, automatic notification features, and data integration from multiple air traffic control centres, enabling the monitoring system to be used on a broader scale.

Conclusions and Suggestions

Conclusions

This research has successfully developed a web-based radar interference monitoring and analysis system integrated with TopSky ATS at Airnav Indonesia Makassar Air Traffic Service Centre (MATSC) Branch. The developed system can process radar log data from Control Work Position (CWP37) devices using a parsing mechanism based on ASTERIX protocol categories 34 and 48, enabling it to detect changes in radar status, record interference events, and automatically calculate the duration of radar failures.

The evaluation results show that the system performs all key operational functions well. The system can display radar status in real time, record the number of radar failure events, and store historical radar interference data in a structured database. Furthermore, the User Acceptance Test (UAT) results showed a user acceptance rate of 93.2%, indicating that the system has excellent levels of ease of use, information quality, and interface quality. Overall, the developed system contributes to increasing the efficiency of the radar monitoring process, reducing reliance on manual recording, and supporting a more systematic and data-driven technical evaluation of radar performance.

Suggestions

Further research could develop a radar monitoring system by integrating Artificial Intelligence (AI) or machine learning to perform predictive analysis of radar performance using historical disruption data. With this approach, the system would not only monitor radar conditions in real time but also predict potential radar failures before operational disruptions occur. Furthermore, future developments could include automatic notification features via email or communication apps when radar status changes, as well as a mobile version to increase flexibility in user access. The system could also be expanded by integrating data from multiple Air Traffic Service Centres to enable more centralised, comprehensive radar monitoring.

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Contributions

All authors made significant contributions to the implementation of this research. The lead author was responsible for the research conceptualisation, system design, and development of the radar monitoring application. Data collection, data analysis, and system evaluation were carried out collaboratively by the entire research team. Manuscript writing, revision, and final approval of the published version were carried out jointly by all authors.

Conflict of Interest

The author declares that there is no conflict of interest in the publication of this article.

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