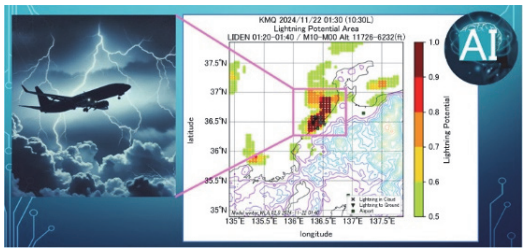
Lilac®: AI-Powered Lightning Strike Risk Prediction



Business Operation Group
Business Development Department
Commercial Aviation Systems
Mitsubishi Heavy Industries, Ltd.

Taking safety in the sky to the next stage with the power of AI.

In aviation, lightning is a natural phenomenon posing a risk that cannot be dismissed. In recent years, the frequency of lightning is increasing, so the damage by lightning strikes is also rising. This has raised concern over increasing economic losses for airlines.

Given these circumstances, Mitsubishi Heavy Industries, Ltd. conducted joint research with Japan Airlines Co., Ltd. and developed an AI model to enable highly accurate prediction of zones in which lightning strikes are likely to occur. This was followed by the start of a support service in April 2024 to help with decision-making to avoid lightning strikes on flying aircraft around Japanese airports. This support service, called "Lilac®", is summarized herein, together with the effects resulting from its implementation.

1. Lightning damage to aircraft and limitations of conventional methods

The recent upward trend in the occurrence of lightning, which is associated with global warming, increases the probability of an aircraft encountering lightning. As Japan is known to be one of the most lightning-prone regions on earth, its airspace requires caution in this regard.

During winter, "winter lightning," whose discharge energy is several times greater than normal lightning in summer, may occur, especially in the coastal areas of the Sea of Japan. This phenomenon of winter lightning is rare, even on a global scale. It is generally difficult to predict when and where it occurs. On the other hand, "aircraft-triggered lightning," which occurs when an aircraft flies through an electrically charged cloud, has also been an issue because of the difficulty of prediction based only on currently available meteorological data.

The avoidance of lightning strikes on aircraft conventionally relied on decisions based on the pilot's experience/visual observation and weather radar data. However, where a thundercloud forms and how it moves are not only very complicated, but also can suddenly change in a short time in many cases. It is therefore difficult to avoid the risk with only human judgment.

Every year in Japan, there are several hundred lightning strikes on aircraft. Quite a few aircraft suffer damage. Especially state-of-the-art aircraft, in which composite materials (such as CFRP) are used for the structure instead of aluminum alloys, require a long repair time because of the complicated processes involved (**Figures 1**, **2**). The consequent expenses for repairs, flight delays/cancellations, and preparation for a substitute aircraft result in an annual economic loss of several hundred million yen domestically.

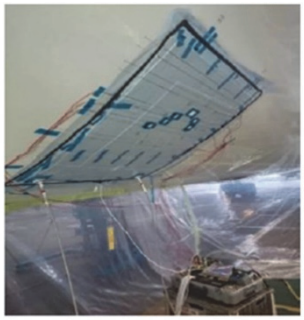
Under such circumstances, Mitsubishi Heavy Industries, Ltd. (hereinafter referred to as MHI) launched joint research with Japan Airlines Co., Ltd. (hereinafter referred to as JAL) in 2019 to enhance the safety and operational efficiency by means of avoiding lightning strikes.

Making use of the knowledge of the lightning risk prediction technology developed by the Japan Aerospace Exploration Agency (hereinafter referred to as JAXA), MHI constructed an original AI-powered prediction model based on observation data from the Japan Meteorological Agency (hereinafter referred to as JMA). In addition, JAL provided feedback based on its experience during actual flights, which was incorporated to augment the technology's accuracy in predicting zones with a high risk of aircraft lightning strikes.

The fruit of this joint research is MHI's "Lilac®" support service to help with decision-making for avoiding lightning strikes on flying aircraft around Japanese airports. It has been in service since April 2024.

Repair of composite fuselage inside clean room to prevent dust/moisture from entering carbon fiber layers

Figure 1 Repair of damage to fuselage made of composite materials*



Carbon fiber layer formation and temperature check, before bonding

Figure 2 Damaged part of fuselage outer surface*

*Provided by courtesy of JAL

2. Features of Lilac

Lilac is a service that is offered to assist the pilot with decision-making by predicting the risk of aircraft lightning strikes. The consequent reduction in lightning damage will improve the operational efficiency. Lilac can be described by the following three features.

2.1 Accurate predictions by AI

In Lilac, an original AI-powered model, which was developed by MHI utilizing JMA's observation data and JAXA's technologies/expertise, predicts in real time where an aircraft is likely to be struck by lightning. The movement of thunderclouds, which was impossible to capture with conventional methods such as weather radar systems and visual observation, has become possible to understand with a quantitative representation of the risk of lightning strikes (**Figure 3**).

As typical cumulonimbus clouds in summer can be detected by airborne weather radar systems or visual observation, it is relatively easy for pilots to avoid them. Aircraft-triggered lightning in winter, however, is difficult to predict with weather radar systems. The AI-powered prediction model in Lilac can make accurate predictions of zones with a high risk both in summer and winter.

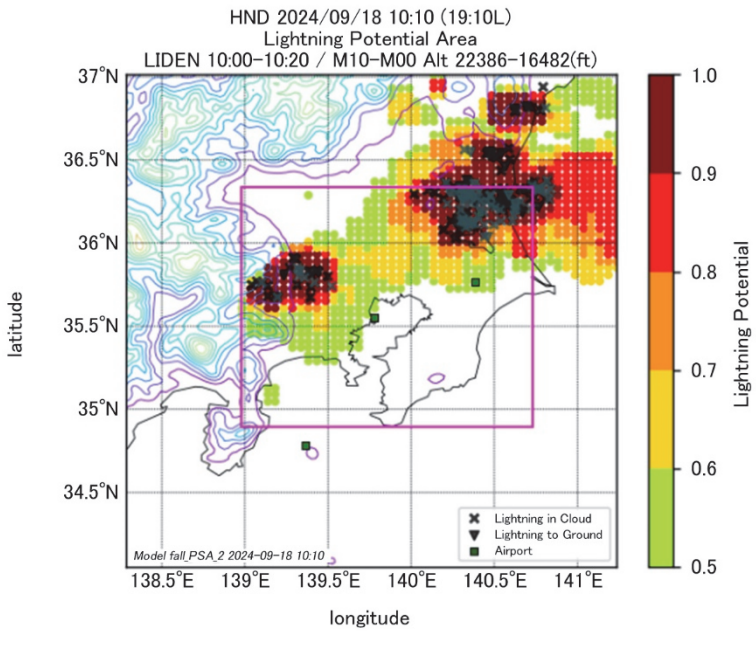


Figure 3 Lightning strike risk color image by Lilac

2.2 No initial costs needed for implementation

Lilac uses JMA's observation data, requiring no equipment for weather observations such as a dedicated radar system. No initial costs are needed to implement Lilac, as the AI model's predictions about lightning strike risk are provided via the Web.

Therefore, the airline operation center can check the predictions on a Web browser. Pilots can also access the same information through cockpit Wi-Fi. At present, however, not all cockpits have a sufficient in-flight connection, although the number of aircraft equipped with cockpit Wi-Fi is increasing. In Lilac, therefore, the Aircraft Communications Addressing and Reporting System (hereinafter referred to as ACARS), which has been in use by airlines for years, is used to send the information to pilots (**Figure 4**).

Figure 4 Conceptual diagram for use of Lilac (flow of information)

2.3 Display of lightning strike risk in a way optimal for each user

In Lilac, the predicted risk information regarding aircraft lightning strikes is displayed in one of the two available formats depending on the role of the user. Specifically, the airline operation center receives the "Color Image Report," whereas pilots get the "ASCII-Art Report." The information can thus be provided in a manner optimal for each work environment (**Figure 5**).

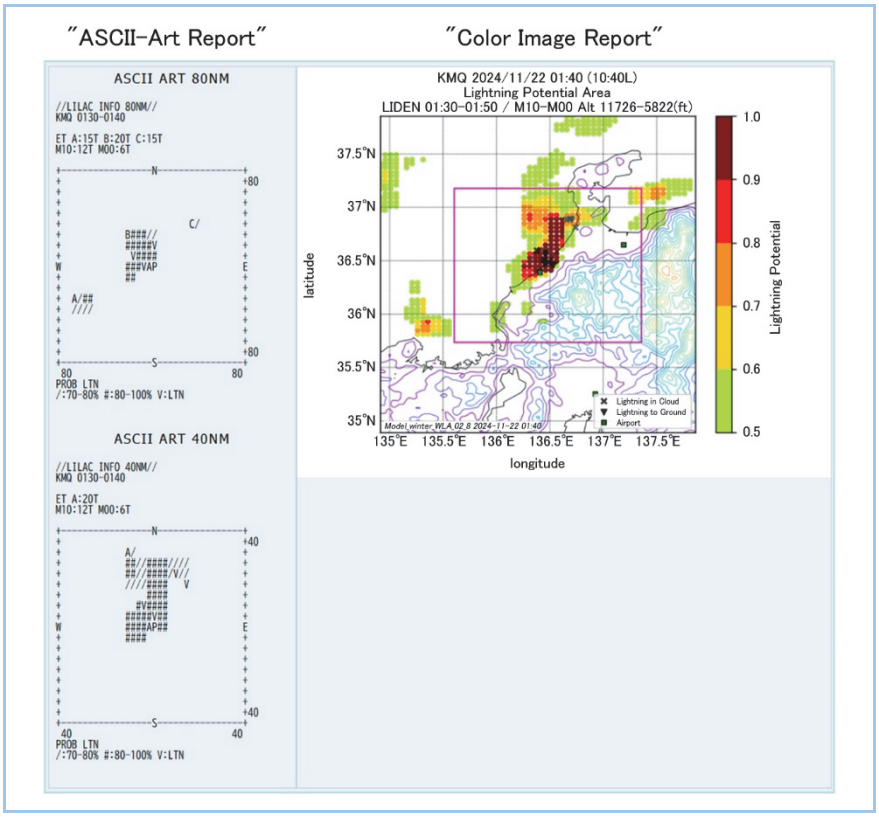


Figure 5 Examples of two formats of data presentation in Lilac

The "Color Image Report" is a colorful representation of data with charts on a Web browser, which enables the airline flight dispatcher to intuitively grasp the risk of lightning strikes. Comparing the latest prediction with past ones makes it possible to chronologically understand the occurrence and change of a zone with a lightning strike risk.

Given to pilots is the "ASCII-Art Report," which has been jointly patented by JAL and MHI. Simple text-based graphics therein, which show the distribution of thunderclouds, are transmitted by ACARS to aircraft. Lilac is thus characterized by the capability of making sure that data are received by the cockpit without depending on the internet connection.

Aircraft are especially prone to lightning strikes during take-off and landing. As these phases involve pilots making many decisions over the aircraft's maneuvering and the surrounding situation, the information to be provided should be simple enough to grasp at a glance. The information presented in ASCII-Art format only contains the data that are necessary but sufficient for pilots to immediately get the picture.

3. Effects of implementation

Since April 2024, Lilac has been in service for take-offs and landings of JAL flights at major airports in Japan. Positive effects have been confirmed since its implementation, and which will be outlined in the following sections.

3.1 Reduced risk of lightning strikes

Lilac's AI-powered prediction model makes it possible to identify in advance where a lightning strike is likely to occur, thereby allowing pilots to take a safer take-off/landing path and timing. As a result, there are now fewer incidents of lightning strikes on aircraft than before the implementation of the system. Especially of note is the number of incidents in 2024, which fell despite lightning occurrences around major airports increasing by a factor of 1.4 from the previous year. This indicates the effectiveness of Lilac in service.

3.2 Prevention of aircraft damage and reduction in maintenance costs

JAL's initiative to avoid lightning strikes, including the implementation of Lilac, has reduced lightning strike occurrences, resulting in fewer incidents of aircraft damage. Moreover, even if lightning did strike, the aircraft damage tended to be less severe because of the capability of taking a safer path, so avoiding a zone with high lightning energy. This leads to a reduction in maintenance/repair costs.

3.3 Stabilization of flight operations and greater customer satisfaction

The lower rate of lightning strikes resulting from taking a safer path helps to prevent disruption to flight operations caused by flight delays/cancellations and preparation for a substitute aircraft. This contributes to enhancing the passengers' sense of security and the reliability of airlines.

4. Future directions

While this service is currently in operation at Japanese airports, MHI aims to implement it to overseas airports with frequent lightning occurrences. The scope of the service will be broadened by adding other functionalities such as forecasting future lightning strikes (e.g., 10 minutes in advance), thereby further contributing to safety in the sky.

Moreover, the information predicted by this service can be provided to not only airports, but also anywhere across Japan. The expansion of its application will be considered for any users facing the problem of lightning strikes on the ground.