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ISERA: An Innovative Simulation to Enhance the Resilience of Aircrew

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Abstract. In this paper we introduce a scenario-based simulation, Innovative Simulation to Enhance the Resilience of Aircrew [ISERA], to develop autonomous and resilient behaviors in, and enhance the responsiveness of the aircrew during emergent situations. ISERA presents various emergency scenarios to individual participants (pilots, cabin attendants, crew, etc.) using slides and tablet computers. The scenarios are all evolving situations, in which additional information and images are presented according to the roles of the participants. Our simulation is unique in that the participants are given the time to discuss possible solutions in more detail as a group, thus enhancing their emergency preparedness knowledge while emphasizing the importance of efficiently sharing information and communicating with colleagues. ISERA helps participants overcome the limitations of previous training by empowering personnel to better think on their feet. If they are trained with only conventional measures, these workers are required to wait for further instruction from a supervisor or dispatcher, on encountering a situation not covered by manuals; consequently, they tend to be reluctant to make decisions and have poor resilience when faced with unexpected events requiring rapid response. We tested ISERA with 45 aircrew personnel comprised of 36 cabin attendants and 9 pilots. Almost all the participants considered ISERA to be highly effective. In particular, they learned that autonomous and resilient behaviors that may not be covered by manuals during emergencies. Although some minor problems must be resolved, we conclude that the ISERA enhances the resilience of aircrew, and thus the safety of aviation.

Keywords: scenario-based simulation, resilience, safety training, emergency, aircrew

1 Introduction

In this study, we developed an innovative training method based on scenario simulations for airline crew; the method does not require a flight or cabin simulator.

Drills involving flight and cabin-evacuation simulators (hereinafter referred to as “simulator training”) are frequently used to promote flight safety. In addition to the regular training required by regulatory agencies, emergency drills are frequently conducted. For example, pilots and cabin attendants are trained for emergent scenarios presented by trainers using simulators.

Although airline crews are well trained, accidents nevertheless occur and crew members cannot prepare for all possible scenarios. Sophisticated training simulations are used but they involve a limited number of scenarios based on past accidents, albeit being well designed. In addition, crew members are mainly trained using mock simulators; they are busy in learning and following manuals and feedback and debriefing are provided by trainers.

In a time of uncertainty marked by social and environmental changes, resilient behaviors are crucial for professionals and the general public in the face of emergencies, such as natural disasters, plant accidents, and airplane incidents. In this paper, we introduce an aircrew training platform to enhance resilience in emergency situations. The platform is also applicable to other contexts, as described in the Discussion section.

People often respond to unexpected real-life situations in a creative and resilient manner. For example, after the crash of Garuda Indonesia Flight 865 at Fukuoka Airport in Japan in 1996, 257 of 260 passengers evacuated the aircraft before the plane burst into flames [1]. Most passengers could not understand the English instructions of the cabin crew, so a young passenger instructed the other passengers to stay calm and then told them how to exit the plane. Although this passenger was not trained in emergency evacuation of aircraft and did not fully understand the English instructions of the crew, he relayed the instructions to the other passengers in an autonomous manner. The passengers followed his lead and successfully evacuated the plane in a timely manner. This was an example of people's flexibility and resilience.

On 11 March 2011, an earthquake struck the Tohoku region and a subsequent tsunami caused severe damage across Eastern Japan. Haga [2] identified three characteristics common to all organizations that functioned well during this crisis. First, the workers of these organizations exhibited flexible thinking and the ability to act according to the circumstances. Second, local organizations and individuals acted autonomously and spontaneously, rather than in a top-down manner, and made their own decisions. Third, the frontline workers understood the organizational mission and acted accordingly. For instance, the crew of one train, which stopped on a hill, told their passengers to stay on board according to the advice of a passenger who lived nearby. The dispatcher instructed the crew to evacuate the train and guide the passengers downhill toward the shelter, as specified in the safety manual. The decision to stay on the train went against the dispatcher's instructions, but all passengers and crew members survived to be rescued the next day because of their noncompliance [2].

Haga et al. [3] interviewed 104 railway operators who encountered the earthquake and explored the general competencies required to successfully cope with natural disasters and other emergencies. These competencies were summarized as professional knowledge and skills, imagination, sensitivity to risk, decision-making ability, and the ability to act. The study demonstrated that operators should not only passively wait for reliable information, but also actively seek it out from various sources and make decisions accordingly.

The above examples of resilient behavior in the face of emergencies might be attributed to personal characteristics. However, as Boin et al. [4] pointed out, effective crisis management can be achieved by creating resilient organizations, rather than relying on any one person (e.g., a leader or hero) to appear in an emergency situation. Therefore, how to create resilient organizations is an important issue. If the individuals working for organizations are able to acquire resiliency and related skills, changes in the organizational climate should occur, thus leading to a more resilient organization over time. Simulation and gaming could be useful to this end. The above-mentioned railway operator, who showed resilience, also cited the importance of a new training program aiming to change the organizational culture by enhancing the resilience of its members.

1.1 Importance of Resilience

Modern society is characterized by volatility, uncertainty, complexity, and ambiguity, termed 'VUCA', due to technological innovation, climate change, and international and domestic conflicts. Resilience engineering was developed to enable socio-technical systems to be resilient under unforeseeable conditions. It was first established in the early 2000s by human-factor specialists, including Erik Hollnagel and David Woods [5]. Among a variety of definitions, Hollnagel [6] defined resilience as

> *"An expression of how people, alone or together, cope with everyday situations - large and small - by adjusting their performance to the conditions. An organization's performance is resilient if it can function as required under expected and unexpected conditions alike (changes/disturbances/opportunities)."*

Hollnagel introduced the Safety-II concept [7]. In contrast to the traditional concept of safety, in which the risk is low and the number of accidents is small, Safety-II is defined as the situation in which as much as possible goes well. Management pursuing Safety-II should ensure that things go right instead of avoiding things going wrong.

Training pertaining to resilience engineering and Safety-II has received increasing attention in multiple industries, including rail transportation, construction, and chemical engineering.

The conventional approach to safety training of personnel uses manuals and standard operating procedures, as implemented by management, to modify the behavior of personnel and prepare them in case of an emergency situation. Front-line operators are trained to follow the instructions of their supervisor or dispatcher in situations where manuals are not applicable. As a result, during unexpected events, these workers lose the ability and willingness to make decisions or act in a resilient manner.

Airplane crews should be able to act in a flexible manner in the event of an emergency, because it is not possible to train for all types of emergencies in advance. However, resilience is difficult to develop using current simulation techniques. Therefore, we developed a new simulation method to enhance the flexibility and resilience of aircrew personnel in the event of an emergent situation requiring a rapid response to save lives. The method was tested on the airline crew who had not previously undergone discussion-based emergency training.

1.2 Innovative Simulation to Enhance the Resilience of Aircrew

Tabletop-exercise-type aircraft simulations have been used previously for training. One sophisticated large-scale tabletop-exercise-type aircraft simulation was developed by Taylor [8]. Another example of emergency simulation developed by Song et al. focuses on passenger evacuation [9], whose theme is very common. Here we introduce the Innovative Simulation to Enhance the Resilience of Aircrew (ISERA). Our ISERA simulation model has several unique characteristics.

First, participants consider possible solutions to various problems; they are given adequate time to discuss creative solutions as a group and fully analyze the situation in an effort to offer the best response. This procedure enhances the ability of participants to identify unexpected events not covered by manuals. In real-time training simulations, even ones involving discussion, participants tend to act or make decisions in accordance with manuals or heuristic techniques due to time pressure. Traditional emergency simulator training involving mock-ups has the same weakness. However, with ISERA participants can take their time to think of better solutions, which ultimately promotes resilience in the face of an emergency.

Second, participants come to realize the importance of sharing information and communicating with colleagues. Our simulation offers an overview of an evolving emergency scenario to all participants, with the ability to provide individual crew members specific additional information according to their role as a crew member via tablet communication. In comparing ISERA to conventional simulation methods, ISERA can be performed by at least one group of five or six participants, whereas other emergency simulators/games require more participants. In ISERA, participants are able to discuss the situations among themselves. As a result, ISERA has a low cost, is easy to use, and is widely applicable.

Third, participants play roles that accord with their actual job responsibilities (pilots and cabin attendants), which increases the applicability of the simulation. According to the concept of the "cone of abstraction" [10], abstract simulations are unconvincing and perceived as unreal by participants. Conversely, if the simulation is highly similar to real life, as is the case for flight simulators and mock-up aircraft emergency training, participants may be overwhelmed by the complexity of the reality and thus fail to understand the key points. Therefore, we developed an intermediate-level simulation.

We developed two scenarios for ISERA. Here, we present the results of one of the scenarios below.

2 Methods

Participants. Two simulations were performed in October 2022 and February 2023. There were 45 participants, including 36 cabin attendants (3 males and 33 females, aged 20–50 years) and 9 pilots (all males, aged 30–60 years).

In the first simulation, 19 participants were divided into three groups: two groups comprised five cabin attendants and one pilot, and the remaining group comprised five cabin attendants and two pilots. In the second simulation, 26 participants were divided into four groups: one group comprised five cabin attendants and two pilots, another comprised six cabin attendants and one pilot, and the remaining two groups comprised five cabin attendants and one pilot.

Scenario. The scenario, which was the scenario was developed in reference to a real airplane accident by the fourth author (a pilot) and refined by the remaining authors.

Table 1 presents the schedule of the simulation. The simulation comprised two sessions with several sub-sessions. During the sub-sessions, a slide that described the situation was presented for almost 3 min, followed by several discussions related to the situation. Then, the participants discussed the scenarios for 15–20 min. In some sessions, the pilots joined the discussion 5 min after the cabin attendants, depending on the scenario.

Table 1. Simulation schedule

	Time
Briefing: Explanation of the significance of the simulation and the procedure	13:00–13:20
Session 1 (three sub-sessions)	13:20–14:20
Break	14:20–14:30
Session 2 (two sub-sessions and presentations)	14:30–15:30
Break	15:30–15:40
Debriefing: Scenario explanation and debriefing	15:40–16:50

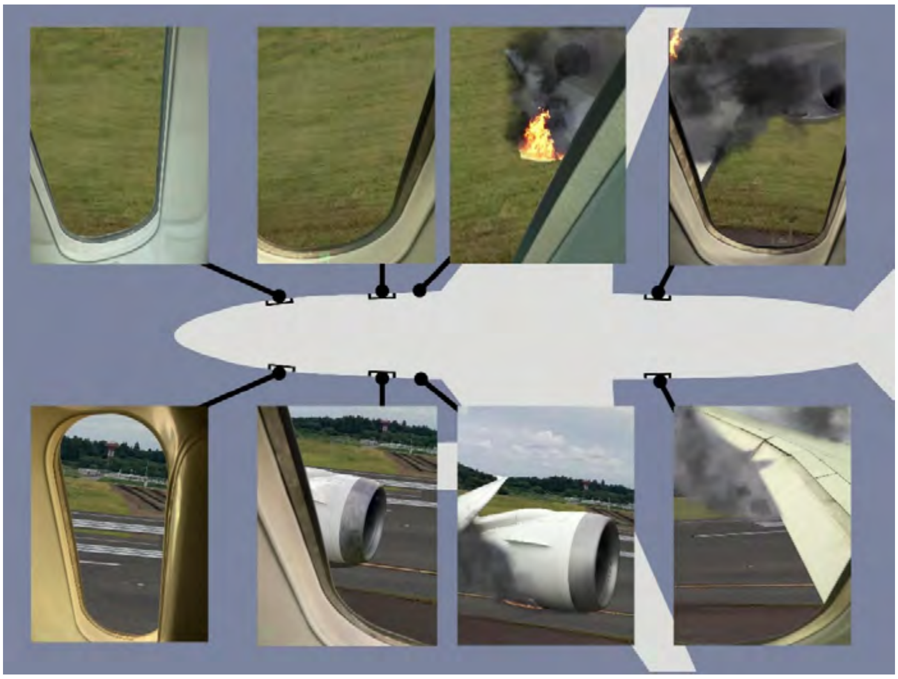

Fig. 1. Photos from the window

The main scenario was shown on the screen for a relatively short time and additional information and images were shown on tablets, according to the roles of the participants. For example, scenery visible from each window of the aircraft was sent to the tablets of the crew, who were responsible for a specific area (Fig. 1). Each crew member was sent only one of the eight photographs shown in Fig. 1. These photos are critical for assessing the situation appropriately and are thus shared among the participants. This is one of the major differences between ISERA and existing emergency training, i.e., situations are described to the trainees in a clearly understandable manner (e.g., via photographs).

During the simulation, cabin attendants were responsible for their allocated areas, similar to real life; however, due to the limited number of participants compared to actual cabin crew, there were no attendants in charge of the two rear doors of the cabin.

The first scenario was a failed "go-around" and runway crash resulting in severe damage to both engines and a fire requiring immediate evacuation.

In this scenario, the fire was not visible from the flight deck; it was visible only to the cabin attendant responsible for a certain area. The pilots would be aware of the fire only when the cabin attendant reported it and would then make a decision regarding evacuating the aircraft. Communication between the flight deck and cabin is necessary, albeit difficult, in the real world.

A crucial point in this scenario is that the cabin crew could see the fire only if the engine was observed from the window located near a particular seat. The cabin attendants had learned this in a simulator and lectures. Once the participants realized this, the group facilitator sent a photograph of the engine fire to the cabin attendant responsible for the area. Otherwise, the groups continued their discussion without this information.

In this type of scenario, cabin attendants are expected to prepare for prompt evacuation before the order to do so is given by the pilot, because even a slight delay could have serious consequences. In other words, the cabin attendants should make an autonomous decision about evacuation in situations where both engines are damaged. The sharing of information (i.e., photographs of scenery) with the flight deck is also crucial.

In this ISERA scenario, there are two key learning points for participants. First, communication between the pilots and cabin crew is crucial; information from cabin attendants is necessary for pilots to make a decision. Second, even if the pilot does not issue an evacuation order due to insufficient information and/or poor communication with the cabin crew, the crew should nonetheless assess the situation (fuel fire and severe damage to both engines) and make an autonomous decision regarding evacuation.

Procedure. In the ISERA simulation (Fig. 2), the main scenario was shown on the screen for a relatively short time (1–2 min). Tablets were used by group facilitators to provide crucial information to the participants, according to their role as part of the flight crew. The simulation comprised two sessions with several sub-sessions. During the sub-sessions, a slide that described the situation was presented for almost 3 min, followed by several discussions related to the situation. Then, the participants discussed the scenarios for 15–20 min as a group.

The first author facilitated the training, while the second and third authors monitored the simulation process. The fourth author (a pilot) explained the scenario during debriefing. The fifth author and other training staff, who are certified trainers for the airline company, facilitated the group sessions.

After debriefing, the participants wrote down what they had learned during the simulation and shared it with the other group members. They were then asked to complete an online questionnaire concerned with the efficacy of the ISERA training exercise.

Fig. 2. A photo during the discussion phase

Dependent variables. The online questionnaire used both quantitative rating scales and open questions. The rating scales were designed to evaluate three main outcomes of ISERA: evaluation of the simulation, self-evaluation of resilience after the simulation, and evaluation of the group discussion. The questions were answered on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Cabin attendants responded to additional questions similar to those asked after training with a real simulator aircraft and scenario training (i.e., conventional training exercises).

Through the open questions of the questionnaire, we collected qualitative data by asking the participants to provide comments about the simulation, given that our approach to emergency training, i.e., training without simulators, was new to the company and crew. This feedback from the crew was considered to be vital for further development of ISERA and frank comments were encouraged for optimizing the platform.

3 Results

3.1 Quantitative Evaluations of the Participants

Table 2 presents the results of the participant evaluations of the simulation. Participants expressed positive opinions about the simulation, which did not involve mock simulators or mandatory lectures by trainers. No differences in responses to the three evaluation items were observed between the participants in the first (n = 19) and second (n = 26) simulations.

Table 3 presents the responses of the participants to the evaluation of items related to resilience. Initially, the participants had low confidence in their ability to prepare for all unexpected scenarios, but they felt better prepared after the simulation. In addition, no differences were found in the responses between the participants in the first and second simulations.

Because group discussion during training was a new concept for the participants, we solicited their opinion regarding such discussion (Table 4). Although the participants were unfamiliar with training through discussion, the group discussions were not considered problematic and were not dominated by certain members. No differences were found in the responses between the participants of the first and second simulations.

Table 2. Mean and standard deviation (SD) values of the responses to the simulation evaluation items

	M	*SD*
I enjoyed the simulation	4.09	1.13
The simulation was important	4.47	0.89
My knowledge about emergency responses was improved	4.56	0.87

Table 3. Mean and standard deviation (SD) values of the responses to the resilience evaluation items

	M	*SD*
Our emergency responses have improved	4.60	0.58
I feel more confident regarding unexpected situations	3.38	0.81
I feel better prepared for unexpected situations	4.11	0.75
We cannot be prepared for all unexpected situations	4.53	0.63

Table 4. Mean and standard deviation (SD) values of the responses to the group discussion evaluation items

	M	*SD*
All members were actively involved in the discussion	4.36	0.96
I was actively involved in the discussion	4.38	0.61
I was able to present my opinions to those in more senior positions	4.36	1.00
The discussion was dominated by some group members	2.80	1.16

We asked the cabin attendants to compare the simulator training to an aircraft mock-up and scenario simulation; few participant responses were recorded (Table 5). Although the participants were unfamiliar with this type of training, their opinions about it were generally positive. No differences were found in the responses between the first and second simulations.

Importantly, in the scenario described, although the engine fire might be visible through other windows, it can be seen most clearly through the window located next to the seat at the right side second door. This was noticed by only one of the seven groups in the two simulations. Therefore, the group facilitator sent a photograph (Fig. 3) to the tablet as soon as the view through the window of the relevant seat was referred to during the discussion.

Table 5. Mean and standard deviation (SD) values of the responses to the simulation evaluation items

	M	***SD***	***N***
This simulation was more enjoyable than simulator training	4.09	0.88	35
This simulation was more useful than simulator training	3.79	0.93	36
The simulation provided us with a deeper understanding of emergencies than simulator training	3.97	0.85	35
We could examine a greater number of situations than with simulator training	4.09	0.76	36
I am better prepared for emergency issues after this simulation than after simulator training	4.30	0.73	36

Fig. 3. A photo from a specific window

3.2 Qualitative Evaluations of the Participants

Given that the discussion-based simulation was a new experience for the participants, they did not have any preconceptions of this training format. As such, we encouraged them to provide frank opinions of ISERA. Some example comments are given below. Notably, we did not analyze their comments systematically, i.e., did not employ text analysis methods.

Eight of the forty-six participants explicitly referred to the difference between a real simulator aircraft and ISERA. As shown by the results in Table 5, they acknowledged the importance of ISERA, in addition to mandatory simulator training. The following comments are typical of the feedback received:

> *"My understanding was deepened by discussing the emergency scenario in detail and hearing other participants' ideas. On the contrary, in simulator training, we have little time to discuss the situation."*

> *"Simulator training provides a sense of reality through smoke and alarms; in this sense, the ISERA simulation was not as realistic. However, scenario simulations have an advantage, in that they offer various scenarios that cannot be replicated by simulators. In my opinion, both types of training are necessary for emergencies, as they have unique advantages and complement each other."*

Eleven participants stated that they became aware of the importance of discussion during emergency training. In a real emergency, there is no time for discussion and an immediate decision will likely be required; therefore, thoroughly discussing the situation before it occurs could increase knowledge of alternatives that the crew could consider. The following comments refer to this point.

> *"Through discussion, we shared our thoughts and learned from other members of the group who had different perspectives and opinions."*

> *"Even though emergencies differ, the fundamentals of communicating with other crew members and dealing with the situation together are similar. Therefore, I will engage in training involving mental imagery by myself."*

The importance of communication, especially between the cabin crew and pilots, was emphasized by many participants. For example, one participant stated the following:

> *"It was a good opportunity for me because I could discuss possible solutions with senior crew members and pilots, which expanded my knowledge."*

In addition, we found that participants often referred to the transfer of knowledge obtained from ISERA to the real world; the following comment exemplifies this:

> *"Since the training was in the form of a tabletop exercise, we could actively exchange opinions, which was very helpful for me. In particular, knowledge about the mechanics of the aircraft and runways provided by the pilots will be useful in my daily work."*

Other comments related to areas of our platform requiring further development in future studies, as presented in the Discussion section.

4 Discussion

The responses of the participants in this study showed that the ISERA simulation training was successful. Because this is the first tabletop-based simulation for aircrews involving group discussion, we were apprehensive about possible negative reactions from the participants, as they would be unfamiliar with this discussion-based format and the simulations did not involve a mock-up aircraft. However, their opinions concerning the new training were generally positive (Table 2).

We expected that ISERA would increase the resilience of the participants during emergencies. Resilience engineering has proposed that the following four basic potentials, or abilities, are necessary: the potentials to respond, monitor, learn, and anticipate [6]. For resilience, these abilities are required at both the individual and organizational level.

Survival during emergencies requires an understanding of how to respond. During the training, the participants did not learn a single "correct" procedure but rather various alternative responses that they suggested themselves. This promotes more resilient behavior during an actual real emergency. The potential to monitor refers to the ability to remain alert and to notice immediately that something is wrong. This ability is based on the potential to anticipate. We instructed the ISERA participants to consider and discuss the current situation, how to prepare for it, and what might happen next. We expected that these exercises would enhance the potentials to monitor and anticipate. Finally, the potential to learn relates to the ability to learn from experiences. At the end of ISERA, the participants wrote down what they had learned during the simulation and shared it with the other group members. Practicing this skill promotes the potential to learn from daily events.

ISERA emphasizes discussion among the aircrew to determine potential solutions. The ability to exchange information, knowledge, and perspective highlights the sharp contrast between ISERA and other types of emergency training. As explained in the Methods section, ISERA includes various scenarios that are not covered by conventional training exercises. Experiencing simulated difficulties, and the need to share information and rapidly uncover potential solutions to an evolving emergent situation with limited information, enhances resilience in real situations.

As shown in Table 3, the participants reported an improved ability to respond to emergencies after ISERA, and felt better prepared for unexpected situations. The ratings indicated high agreement with the statement "We cannot be prepared for all unexpected situations". Once aircrews realize that they cannot be prepared for all unexpected situations, they will be better able to cope with emergencies themselves rather than wait for directions. However, the ratings for the statement "I feel more confident regarding unexpected situations," did not reflect increased confidence after ISERA training. In a traditional evacuation training using a mock-up cabin, cabin attendants learn what to do after an order has been given to evacuate, which may lead to overconfidence. However, in real life, there are infinite possibilities. ISERA exposes participants to various situations beyond the scope of manuals. The realization that there are virtually infinite possibilities in emergency situations may decrease the confidence of participants. However, the confidence of participants regarding their ability to cope with unexpected events may be enhanced by repeated ISERA simulation training.

Cabin crews have a well-defined hierarchy. We considered the possibility that discussion might be dominated by a few participants (e.g., pilots or senior attendants) such that not all participants would be actively involved. However, Table 4 shows that the participants did not hesitate to present their opinions and individual participants did not dominate the discussion. Therefore, ISERA promotes lateral communication and autonomous actions during emergencies. In fact, in this scenario, there is scope for autonomous and resilient behavior, i.e., decision-making related to evacuation in the absence of a command from the captain. If applied to real life, the experience acquired through the simulation may improve resilience.

Table 5 shows that the participants responded more favorably to ISERA than to simulator training. Notably, the score for the item related to awareness of issues was higher than that for simulator training. While simulator training is indispensable for emergency training, introducing tabletop simulations with discussion components may be useful to enhance the resilience of crew members.

In summary, ISERA can help aircrew acquire the autonomous and resilient behaviors required in emergencies, but which are not necessarily covered by manuals.

This study had some limitations. First, we obtained only subjective ratings from the participants; future studies should collect data related to performance improvement, although this is difficult to measure in real emergencies, particularly in relation to resilience. Because performance changes cannot be measured directly, long-term evaluations are needed. Future studies could ask participants how the current simulation impacted their work, as improvements in resilience may not emerge in the short term. Second, the analysis of qualitative data should be refined. In this paper, we only provided some of the participants' comments, and we did not apply a systematic method of qualitative data collection and analysis. The participants seemed hesitant when answering the questions, perhaps because ISERA is an unfamiliar emergency training platform; therefore, we did not adopt the typical methods used for collecting data in academic research. Nevertheless, as mentioned in previous sections, the participants' comments contain information that could inform future studies. More adaptive quantitative and qualitative methods to determine learning outcomes are needed. Finally, and most importantly, the simulation should be further refined. A major advantage of ISERA is its low cost and that it does not require a large training facility or expensive equipment. However, at least one facilitator per group is necessary to transfer the required information to the tablets in a timely manner. Recruitment of a sufficient number of facilitators may be difficult if ISERA is conducted with a larger number of participants.

Despite the limitations of this study, the results suggest that ISERA may enhance the resilience of airline crews, and thus the safety of aviation. We are continuing to improve our simulation and plan to conduct further simulations and report our results in the near future. Although ISERA was originally developed for aircrew training, we believe that it could also be applied to aid the emergency responses to plant accidents and natural disasters, which also require rapid mitigation measures to save lives.

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