Enhancement of a Lightning Alert System for Maintenance Repair Organization

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Abstract- ***Thunderstorms and lightning strikes have always posed a safety risk for people working outside, particularly those working on airport ramps, where the workflow is continuous even during different weather events at any time of day. This study determined the implementation of the current lightning alert system used in the Maintenance Repair Organization and a proposed enhancement of the lightning alert system that was designed to lessen the flow or alerting process. The data was collected by a descriptive survey questionnaire with a 4-point Likert scale for the level of implementation and level of agreement with the assistance of fifty (50) affected aircraft maintenance personnel of Lufthansa Technik Philippines. The survey questionnaire also includes a checklist for common issues and concerns that the affected participants encountered and asks them to fill out a survey with suggestions that they think would suit an effective lightning alert system based on their experiences with the current lightning alert system. This study revealed the need to enhance the current lightning alert system that will be utilized in terms of hardware, alerting process, evacuation facilities, and detailed policies and procedures.***

I. INTRODUCTION

Lightning and thunderstorms impose high safety risks on personnel working outdoors. During thunderstorms and lightning events, employees and ground operators working on airport ramps are routinely exposed to lightning hazards.

To ensure the safety of outdoor airport ramp workers, airport authorities and operators issue warning alerts when thunderstorms form in the vicinity of the airport. The typical system includes signal operators and others working with electronic instrumentation for the lightning alert system. In addition, thunderstorm activity can be identified as the primary factor reducing the operational efficiency of airports, and it is difficult to strike a balance between personal safety and operational efficiency (Maduranga, 2021).

By this, airport authorities and operators issue an advisory for a "work stoppage" order to the ground operations. Depending on their policies, Maintenance Repair Organizations (MRO) also disseminate the "work stoppage" advisory given by the authorities to their ground personnel to halt maintenance tasks. Airport authorities and airport operators are also the ones who will lift the "work stoppage" order when they determine that the lightning threat has passed. However, these alerts and warnings from the authority's command center are sometimes limited to only airport terminals and operation-critical zones. MROs are frequently located on the edge of the airport from the terminals, so they cannot effectively receive the alarm from the alert system installed on the airport terminals. As a result, they rely on a phone call, email, or SMS message from the aerodrome command center. This type of information flow causes a delay in alarm notification between the airport command center and the affected ground personnel of MROs.

Other countries have invested in their alerting system for lightning for better advisory delivery. For example, a standard system uses different methods such as Push notifications, personalized and detailed SMS alerts for personnel in critical zones, full coverage for audible and visible warnings, nowcasting, and forecast of thunderstorms with an estimated countdown before the storm hits (North, 2020).

Vulnerability to lightning strikes is growing due to the increased severity and frequency of convective storms. Lightning hazards pose risks to personnel safety and may cause power outages. Therefore, they can impact the reliability and performance of the airport's facilities if they are not appropriately fortified (He, 2019). This damage also causes airline and operational delays, increasing costs and decreasing efficiency. Lightning strikes and thunderstorms are unavoidable, but an adequate warning and alert system can save lives, reduce injuries, and prevent false and unnecessary alarms. This system also reduces property damage and delays in operations (Adekitan, 2021).

A lightning protection system can significantly suppress the lightning current flowing in the grounding electrode for internal equipment (Deshagoni, 2019). That is why effective lightning protection systems are also integral to risk reduction for lightning strikes. Different protection systems can also be applied for lightning alert systems used in airports to ensure the safety of the structures and ground personnel (Negara, 2021).
Given the preceding, the researcher studied how to enhance the current lightning alert system for use by local MRO. Likewise, the study will demonstrate how the existing alert system and its procedures could be enhanced to reduce the risk of injuries by outcome recommendations for the alerting process and the applicable protection devices that increase the safety of the Maintenance Repair Organizations' ground personnel.

II. PROCEDURE

- Methods of Research

In descriptive research, specifically survey methodology, the current lightning alert system of Lufthansa Technik Philippines was evaluated using this method. According to Mishra (2019), descriptive statistics are used to summarize a set of observations to convey as much information as possible in the simplest manner. Descriptive statistics are the data presented in a few words to describe the fundamental characteristics of a study's data.

This study also involved the researcher using a survey questionnaire with a section for a personnel experience checklist and collecting suggestions for improving the system.

- Population and Sampling

The participants of the study are composed of the affected personnel working in the MA3 department of Lufthansa Technik Philippines (LTP), which consists of twenty (20) Airframe and Powerplant mechanics, twenty (20) Radio, Equipment, and Instrument mechanics, and ten (10) Structures and Materials mechanics. In addition, the participants were handed a checklist to help describe their experiences with the current lightning alert system, and in addition, they were asked what suggestions they thought would further enhance the current system for lightning alert system of LTP.

- Data Gathering Procedures

In the first part, a survey was collected about the participant's level of implementation and level of agreement using a 4-point Likert scale. With the guidance of an infographic, the presentation is backed up with an illustration that shows the overview of the current lightning alert system and the proposed enhancement of the lightning alert system used in Lufthansa Technik Philippines (LTP). This system helped the participants to respond accurately to the questionnaire. This process connects to Nemoto's (2014) paper in which he stated that a Likert scale is a psychometric scale with multiple categories from which respondents choose to indicate their opinions, attitudes, or feelings about a particular issue. In another part of the data collection, the researcher used a checklist to know the common issues and concerns encountered in the existing lightning alert system. Lastly, the researcher asked for suggestions from the participants for enhancing the lightning alert system.

- Statistical Treatment of Data

Statistical techniques and tools will be used to ensure a systematic and reliable presentation, analysis and interpretation of gathered data from the survey questionnaire and for testing the null hypothesis.

III. RESULTS

The demographic profile of the participants in terms of:

Table 1
Frequency & Percentage Distribution of Demographic Profile of the Participants

Particulars	Category	Frequency f	Percentage %
Department/ Section/Skills	MA31 A&P - Airframe and Powerplant	20	40.00
	MA32 REI - Radio, Electronics & Instruments	20	40.00
	MA33 S/M - Structures	10	20.00
	Total	**50**	**100**
Length of Service	Less than 5 years	13	26.00
	6-10 years	26	52.00
	11-15 years	6	12.00
	16-20 years	5	10.00
	Total	**50**	**100**

Table 1 shows the frequency and percentage distribution of the participants' specializations. 20 or 40% are from MA31 A&P - Airframe and Powerplant and MA32 REI - Radio, Electronics & Instruments 20 or 40%, however, for MA33 S/M– Structures their official total population is 17 only and quarter of them were stationed in different airports in the Philippines in the time that this study was conducted that's the reason why the researcher opted for ten (10) participants for MA33 S/M that make up the remaining 20% of the total participants. The table also presents those 13 participants, or 26%, have worked for Lufthansa Technik Philippines for less than five years, 26 participants, or 52 percent, have worked there for six to ten years, 6 participants, or 12 percent, have worked there for eleven to fifteen years and 5 or 10% for sixteen to twenty years. This implies that many aircraft maintenance personnel working in Lufthansa Technik Philippines decreases after ten years since the initial service contract is only applicable for seven years (LTP-HR, 2022). This data varies depending on the personnel's needs. According to Abenir (2019), when able, adult family members frequently seek employment opportunities overseas to increase their family's economic prosperity. As a primary source of income for the nation, these individuals are frequently hailed as "heroes" for their sacrifice and willingness to go abroad and send money home to assist the struggling national economy.

Level of implementation of the current lightning alert system used in Lufthansa Technik Philippines the terms of:

SAFETY

Table 2
Mean Distribution of the Participants on the Level of Implementation of the Current Lightning Alert system used in Lufthansa Technik Philippines in Terms of Safety

INDICATOR	MA31 A&P	MA32 REI	MA33 S/M	MEAN	VI	RANK
1. Cease of all aircraft ground servicing.	2.75	3.00	3.10	2.92	I	2
2. Suspension of maintenance tasks performed on the aircraft's external (landing gear, wings, engines, and others).	2.70	2.85	3.30	2.88	I	3
3. Cease of aircraft towing and marshaling services.	2.75	2.95	2.90	2.86	I	4
4. Removal of all ground service equipment from the aircraft (Air steps, Ground power unit, air power unit).	1.95	2.10	2.10	2.04	PI	8
5. Loading and unloading of catering services.	2.60	2.70	2.80	2.68	I	5
6. Directions to evacuation sites are cascaded and are easily accessible to ground personnel on the ramp.	2.25	2.60	2.70	2.48	PI	6
7. Suspension of operation for ground vehicles with an open cab on the ramp.	2.30	2.50	2.60	2.44	PI	7
8. Suspension of fueling and de-fueling operation.	2.80	3.00	3.10	2.94	I	1
WEIGHTED MEAN	**2.51**	**2.71**	**2.83**	**2.65**	Implemented	

LEGEND: VI (Verbal Interpretation); 1.00 – 1.74 Not Implemented (NI); 1.75 – 2.49 Partially Implemented (PI); 2.50 – 3.24 Implemented (I) 3.25 – 4.00 Fully Implemented (FI)

Table 2 shows that implementation of safety in terms of the suspension of fueling and de-fueling operation ranked number 1 (M=2.94) after the cease of all aircraft ground servicing (M=2.92) and suspension of maintenance tasks performed on the aircraft's external (landing gear, wings, engines, and others) (M=2.88). Moreover, ranked last is removing all ground service equipment from the aircraft (Air steps, Ground power unit, air power unit) (M=2.04). Furthermore, an overall weighted mean is 2.65 or "Implemented."

This data implies that "Removal of all ground service equipment from the aircraft," even though it is part of the variable safety, is not appropriately implemented where it should be highly implemented since it reduces the exposure of risk and may save the lives of the maintenance personnel.

TIMELINESS

Table 3
Mean Distribution of the Participants on the Level of Implementation of the Current Lightning Alert System Used in Lufthansa Technik Philippines in Terms of Timeliness

INDICATOR	MA31 A&P	MA32 REI	MA33 S/M	MEAN	VI	RANK
1. Alert information is relayed on time.	2.15	2.40	2.70	2.36	PI	2
2. Resume of operation is relayed on time.	2.60	2.60	2.80	2.64	I	1
3. Duration of the alert is sufficient to ensure that all affected are notified and evacuated.	2.20	2.35	2.60	2.34	PI	3
WEIGHTED MEAN	**2.32**	**2.45**	**2.70**	**2.45**	**Partially Implemented**	

LEGEND: VI (Verbal Interpretation); 1:00 – 1.74 Not Implemented (NI); 1.75 – 2.49 Partially Implemented (PI); 2.50 – 3.24 Implemented (I) 3.25 – 4.00 Fully Implemented (FI)

Table 3 reveals that the overall weighted mean value in terms of timeliness is 2.45, which is verbally translated as "Partially Implemented," where the item duration of the alert is sufficient to ensure that all affected are notified and evacuated (M=2.34), ranked last and is translated as "partially implemented" or M=2.45. This implies that some of the participants are unaware of lightning event or if the alert has been lifted.

According to Qing Meng (2019), the technology needed to support an effective alert for personnel protection depends on the actual critical procedures to curtail operations. This system includes methodical evacuation to safe location procedures and accurate transmission of resume to operation when deemed safe from a lightning strike.

ALERT NOTIFICATION

Table 4
Mean Distribution of the Participants on the Level of Implementation of the Current Lightning Alert System Used in Lufthansa Technik Philippines in Terms of Alert Notification

INDICATOR	MA31 A&P	MA32 REI	MA33 S/M	MEAN	VI	RANK
1. Automation of lightning alert using targeted SMS.	1.65	2.05	2.20	1.92	PI	2
2. Automation of lightning alert using push notifications.	1.55	1.75	1.90	1.70	PI	4
3. Activation of an aural warning for a lightning alert.	1.40	1.55	2.00	1.58	PI	6
4. Activation of a visual warning for a lightning alert.	1.40	1.68	1.90	1.61	PI	5
5. Handheld radio transmission of lightning alert.	1.65	1.70	2.60	1.86	PI	3
6. Alert notification using a mobile device.	2.15	2.25	2.60	2.28	PI	1
WEIGHTED MEAN	**1.63**	**1.82**	**2.20**	**1.82**	**Partially Implemented**	

LEGEND: VI (Verbal Interpretation); 1:00 – 1.74 Not Implemented (NI); 1.75 – 2.49 Partially Implemented (PI); 2.50 – 3.24 Implemented (I) 3.25 – 4.00 Fully Implemented (FI)

Table 4 reveals the partial implementation of alert notification has a weighted mean of 1.82 and ranks alert notification using a mobile device (M=2.28) first, followed by automation of lightning alert using targeted SMS (M=1.92) and handheld radio transmission of lightning alert (M=1.86). These findings imply that among the criteria, there is some partial implementation in using mobile devices as alert notifications. This shows that among all of the devices for alerting the personnel during a lightning alert, the participants rely on their personal mobile devices.

POLICIES & PROCEDURES

Table 5
Mean Distribution of the Participants on the Level of Implementation of the Current lightning Alert System Used in Lufthansa Technik Philippines in Terms of Policies & Procedures

CRITERIA	MA31 A&P	MA32 REI	MA33 S/M	MEAN	VI	RANK
1. Evacuation command from Maintenance Control Center.	2.00	2.30	2.90	2.30	PI	1
2. Documentation about policies and procedures is distributed and accessible.	2.00	2.15	2.30	2.12	PI	3
3. Policies and procedures regarding lightning alerts are taught.	2.15	2.20	2.60	2.26	PI	2
WEIGHTED MEAN	**2.05**	**2.22**	**2.60**	**2.23**	**Partially Implemented**	

LEGEND: VI (Verbal Interpretation); 1:00 – 1.74 Not Implemented (NI); 1.75 – 2.49 Partially Implemented (PI); 2.50 – 3.24 Implemented (I) 3.25 – 4.00 Fully Implemented (FI)

The participants view the current lightning alert system policies and procedures as partially implemented, with a weighted mean score of 2.23, as shown in Table 10. Where Evacuation command from Maintenance Control Center (M=2.30) ranks first, Policies and procedures regarding lightning alerts are taught (M=2.26) second, and Documentation about policies and procedures is distributed and accessible (M=2.12) or "partially implemented" ranks last, which implies that in the current system the participants feels

that the evacuation process lacked in the aspect alert notification for the personnel working in the ramp.

Table 6
Summary Mean Distribution of the Participants on the Level of Implementation of the Current Lightning Alert System Used in Lufthansa Technik Philippines

CRITERIA	MEAN	STANDARD DEVIATION	VERBAL INTERPRETATION	RANK
1. Safety	2.65	0.569	Implemented	1
2. Timeliness	2.45	0.616	Partially Implemented	2
3. Alert Notification	1.82	0.723	Partially Implemented	4
4. Policies and Procedures	2.23	0.654	Partially Implemented	3
WEIGHTED MEAN	**2.29**	**0.641**	**Partially Implemented**	

LEGEND: VI (Verbal Interpretation); 1.00 – 1.74 Not Implemented (NI); 1.75 – 2.49 Partially Implemented (PI); 2.50 – 3.24 Implemented (I) 3.25 – 4.00 Fully Implemented (FI)

The overall mean distribution of the participants on the level implementation of the current lightning alert system used in Lufthansa Technik Philippines is shown in Table 10. As indicated in the table, participants on the level of implementation of the current lightning alert system used in Lufthansa Technik Philippines got a general weighted mean of 3.09 with a standard deviation of 0.172, which was verbally translated as "Implemented," where safety ranked first, and "Alert Notification" or M = 1.82, which was verbally translated as "partially implemented," ranked last. Since the average is "Partially Implemented," it suggests that the application of each criterion, which has a disproportionate impact, greatly raises the safety risks for the affected personnel working on the MROs ramp. Participants who are impacted notice safety issues at various phases of implementation.

Significant Difference of the Participants on the Level of Implementation of the Current Lightning Alert System Used in Lufthansa Technik Philippines

Table 7
Significant Difference on the Perception of the Participants in the Level of Implementation of the Current Lightning Alert System Used in Lufthansa Technik Philippines

VARIABLES	SPECIALIZATION	N	MEDIAN	MEAN RANK	H	SIG	DECISION
1. Safety	MA31 A&P	20	2.313	21.5	2.81	0.246	Accept H_0
	MA32 REI	20	2.813	27.3			
	MA 33 S/M	10	2.750	30.1			
2. Timeliness	MA31 A&P	20	2.000	22.1	3.72	0.156	Accept H_0
	MA32 REI	20	2.167	25.4			
	MA 33 S/M	10	2.667	32.6			
3. Alert Notification	MA31 A&P	20	1.500	21.8	3.98	0.137	Accept H_0
	MA32 REI	20	1.500	25.5			
	MA 33 S/M	10	2.333	33.0			
4. Policies and Procedures	MA31 A&P	20	2.000	21.0	5.97	0.051	Reject H_0
	MA32 REI	20	2.000	25.5			
	MA 33 S/M	10	2.500	34.5			

LEGEND: N = Population; H (Kruskal-Wallis H-Tab); Sig (P-Value)

Table 7 presents the Kruskal-Wallis H-Test shows the significant difference in the level of implementation between the three groups of participants of the current lightning alert system used in Lufthansa Technik Philippines concerning different criteria. It can be seen from the table that it was statistically found that there is no significant difference in the level of implementation to safety (H=2.81, p=0.246), timeliness (H=3.72, p=0.156), and alert notification (H=3.98, p=0.137). Thus, the null hypothesis is accepted. On the other hand, there was a statistically significant difference in the level of implementation between the three groups of participants of the current lightning alert system used in Lufthansa Technik Philippines concerning policies and procedures (H=5.97, p=0.051). Thus, the null hypothesis is rejected. Even though the variable "Policies and Procedure" rejected the null hypothesis, the participants' perception in terms of verbal interpretation of the data is only "Partially Implemented." This result means that although policies and procedures are somewhat imposed, the participants are still at risk because of the lack of defined roles and responsibilities among the affected maintenance personnel to execute procedures. The miscommunication and confusion about the policies and procedures can result in aircraft delays or, worse, injury or death. Furthermore, the significant disparity in terms of "safety," "timeliness," and "Alert notification" categorical variables are accepted, which means that the perception of the respondents finds the level of implementation from the terms above is highly significant. The participants are aware of the lack of implementation from those categories since the verbal interpretation is, at best, "implemented" and "partially implemented" only. Moreover, the implication is that there is no significant difference which means that the escalation of accidents, injuries, and adverse health effects is correlated with variables closely related to operations management. Regardless of what causes

fluctuations in the number of incidents, the numbers indicate that workplace safety is an issue that cannot be ignored (Passetti,2020).

The level of agreement with the proposed enhanced lightning alert system for Lufthansa Technik Philippines of in terms of Function Suitability

Table 8
Significant Difference on the Perception of the Participants in the Level of Implementation of the Current Lightning Alert System Used in Lufthansa Technik Philippines

INDICATOR	MA31 A&P	MA32 REI	MA33 S/M	MEAN	VI	RANK
1. **Functional Completeness**. The policies and procedures for lightning alerts can guide the ground personnel to the standard operating procedures during a lightning alert.	3.50	3.60	3.40	3.52	SA	1
2. **Functional Correctness**. The proposed systems' medium for alert notification (SMS, Phone call, Handheld Radio) can assist the ground personnel during a lightning event.	3.40	3.50	3.40	3.44	SA	2
3. **Functional Appropriateness**. The proposed system aids in the reduction of lost time in maintenance tasks during the lightning event.	3.00	3.35	2.70	3.08	A	3
WEIGHTED MEAN	**3.30**	**3.48**	**3.17**	**3.35**	**Strongly Agree**	

LEGEND: VI (Verbal Interpretation); 1.00 – 1.74Strongly Disagree (SD); 1.75 – 2.49 Disagree (D); 2.50 – 3.24 Agree (A) 3.25 – 4.00 Strongly Agree (SA)

According to Table 8, functional appropriateness (M=3.08) ranked last, followed by functional correctness (M=3.44) and functional completeness (M=3.52) has the highest level of agreement. This implies that in the participants perception, the functional suitability of the enhanced system provides the required guidance and correct results that can accomplish the objectives of the policies and procedures, alerting procedures, and reduction of lost time during a lightning event in the LTP ramp.

Performance Efficiency

Table 9
Mean Distribution of the Participants Level of Agreement with the Proposed Enhanced Lightning Alert System for Lufthansa Technik Philippines in Terms of Performance Efficiency

INDICATOR	MA31 A&P	MA32 REI	MA33 S/M	MEAN	VI	RANK
1. **Time Behavior.** The response time upon the receipt of the alert is timely.	2.85	3.30	3.00	3.06	A	3
2. **Resource Utilization.** Notifying personnel using a mobile device as a medium is efficient.	3.15	3.20	3.00	3.14	A	2
3. **Capacity.** The proposed system can cover the entirety of the LTP ramp.	3.30	3.40	2.80	3.24	A	1
WEIGHTED MEAN	**3.10**	**3.30**	**2.93**	**3.15**	**Agree**	

LEGEND: VI (Verbal Interpretation); 1.00 – 1.74Strongly Disagree (SD); 1.75 – 2.49 Disagree (D); 2.50 – 3.24 Agree (A) 3.25 – 4.00 Strongly Agree (SA)

Table 9 reveals that the weighted mean for all variables in Performance Efficiency in terms of Capacity (M=3.24), which ranks first, Resource utilization (M=3.14), and "Time behavior" was 3.15, or overall Agree (3.15). This data implies that the participants deem the system's capacity sufficient to give coverage to the entire LTP ramp.

Usability

Table 10
Mean Distribution of the Participants Level of Agreement with the Proposed Enhanced Lightning Alert System for Lufthansa Technik Philippines in Terms of Usability

INDICATOR	MA31 A&P	MA32 REI	MA33 S/M	MEAN	VI	RANK
1. **Appropriateness Recognizability**. The proposed alert system is easy to understand and interpret.	3.40	3.50	3.20	3.40	SA	3
2. **Learnability**. The infographic and the proposed flow process are easy to understand and follow.	3.45	3.60	3.20	3.46	SA	2
3. **User Error Protection**. The proposed enhancement of the lightning alert system may reduce errors in interpretation because of its distinctness	3.45	3.50	3.00	3.38	SA	4
4. **Accessibility.** The lightning alert system proposed in LTP can be used in other facilities, not just in the aviation industry.	3.55	3.55	3.30	3.50	SA	1
WEIGHTED MEAN	**3.46**	**3.54**	**3.17**	**3.44**	**Strongly Agree**	

LEGEND: VI (Verbal Interpretation); 1.00 – 1.74Strongly Disagree (SD); 1.75 – 2.49 Disagree (D); 2.50 – 3.24 Agree (A) 3.25 – 4.00 Strongly Agree (SA)

Table 10 reveals that “Accessibility” ranks highest in the Usability criteria for the proposed enhanced lightning alert system for Lufthansa Technik Philippines, with a weighted mean of 3.5 or “Strongly Agree.” User error protection” ranks lowest, with a weighted mean of 3.38, or “Strongly Agree,” but still on the “Strongly agree” scale. This means that in terms of usability, the participants regard the proposed

enhanced system with its effectiveness, efficiency, and a wide range of characteristics to achieve safety in the ramp.

Reliability

Table 11
Mean Distribution of the Participants Level of Agreement with the Proposed Enhanced Lightning Alert System for Lufthansa Technik Philippines in Terms of Usability

CRITERIA	MA31 A&P	MA32 REI	MA33 S/M	MEAN	VI	RANK
1. **Maturity.** The proposed enhancement of the lightning alert system meets the reliability requirement needed in a lightning event.	3.45	3.40	3.20	3.38	SA	3
2. **Availability.** The proposed enhancement of the lightning alert notification methods is available at any time of the day.	3.40	3.45	3.60	3.46	SA	1
3. **Fault Tolerance.** The enhancement of the alert system will still be noticeable even if one of the mediums for notification is inoperative.	3.45	3.45	3.30	3.42	SA	2
4. **Recoverability.** In the event of a total failure of the system (Aural and Visual Warning), personnel will still be able to evacuate during a lightning event.	3.30	3.40	3.20	3.32	SA	4
WEIGHTED MEAN	**3.40**	**3.42**	**3.33**	**3.40**	**Strongly Agree**	

LEGEND: VI (Verbal Interpretation); 1.00 – 1.74Strongly Disagree (SD); 1.75 – 2.49 Disagree (D); 2.50 – 3.24 Agree (A) 3.25 – 4.00 Strongly Agree (SA)

Table 11 shows that the total weighted mean for the level of agreement with the proposed enhanced lightning alert system for Lufthansa Technik Philippines in terms of Reliability is 3.40, which is verbally interpreted as "Strongly Agree." Availability (M=3.46) ranks first, followed by fault tolerance (M=3.42), maturity (M=3.38), and recoverability, all verbally interpreted as "Strongly Agree." This result implies that most participants believe that accessibility in terms of lightning alert systems can be used for different types of alerts in different fields or industries (Fawzi, 2019) where, the proposed enhancement of the system meets the operations accessibility when required.

Maintainability

Table 12
Mean Distribution of the Participants Level of Agreement with the Proposed Enhanced Lightning Alert System for Lufthansa Technik Philippines in Terms of Maintainability

CRITERIA	MA31 A&P	MA32 REI	MA33 S/M	MEAN	VI	RANK
1. **Modularity.** Different modes of communication can be used in case of failure and retain their effectiveness.	3.40	3.25	3.40	3.34	SA	3
2. **Reusability.** The alert system can be used on different types of alerts.	3.40	3.45	3.40	3.42	SA	2
3. **Modifiability.** The Alert system can be modified with new systems if available.	3.40	3.45	3.50	3.44	SA	1
WEIGHTED MEAN	**3.40**	**3.38**	**3.43**	**3.40**	**Strongly Agree**	

LEGEND: VI (Verbal Interpretation); 1.00 – 1.74Strongly Disagree (SD); 1.75 – 2.49 Disagree (D); 2.50 – 3.24 Agree (A) 3.25 – 4.00 Strongly Agree (SA)

The general weighted mean for "modifiability" was 3.40, or "Strongly Agree," according to Table 12. This finding was the highest level of an agreement after "reusability" and "modularity." This result indicates that participants agreed that the proposed alert system would be adaptable to new systems since it can be modified improve it when new alerting devices are available.

Table 13
Summary Mean Distribution of the Participants Level of Agreement with the Proposed Enhanced Lightning Alert System for Lufthansa Technik Philippines in Terms of the Following Variables

VARIABLES	MEAN	STANDARD DEVIATION	VERBAL INTERPRETATION	RANK
1. Functional Suitability	3.35	0.602	Strongly Agree	4
2. Performance Efficiency	3.15	0.660	Agree	5
3. Usability	3.44	0.522	Strongly Agree	1
4. Reliability	3.40	0.523	Strongly Agree	2.5
5. Maintainability	3.40	0.504	Strongly Agree	2.5
WEIGHTED MEAN	**3.35**	**0.562**	**Strongly Agree**	

LEGEND: VI (Verbal Interpretation); 1.00 – 1.74Strongly Disagree (SD); 1.75 – 2.49 Disagree (D); 2.50 – 3.24 Agree (A) 3.25 – 4.00 Strongly Agree (SA)

The overall mean distribution of the participants on level of agreement with the proposed enhanced lightning alert system for Lufthansa Technik Philippines is shown in Table 17. As indicated in the table, participants' level of agreement with the proposed enhanced lightning alert system for Lufthansa Technik Philippines got a general weighted mean of 3.35 with a standard deviation of 0.562, which is verbally interpreted as strongly agree. The overall implications are that the participants viewed the proposed enhancement of the lightning alert system in terms of the variables for its level of agreements is relevant since, it has the trait of being effective for its accuracy and completeness, efficiency for the resources expended for the system, and flexibility that enables the system to adapt to newer technologies, this term supports to uphold of safety in the ramp during a lightning event. This implies that that there is a need for the enhancement of the lightning alert system used

in Lufthansa Technik Philippines, where policies and procedures for the person can properly guide maintenance personnel through the procedures during lightning activity, as well as the importance of redundancy in broadcasting and the disseminating of information that can lead to an increase in safety and a reduction in maintenance tasks' lost time. According to Peters (2020), the usability factor, the extent to which a system can be used to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use, is characterized. The usability factor comprises several sub-factors: appropriateness, recognizability, learnability, operability, user error protection, user interface aesthetics, and accessibility. Since usability is an important quality factor for all systems, the system quality model has been modified accordingly.

The significant difference on the level of agreement with the proposed enhanced lightning alert system for Lufthansa Technik Philippines in terms of

Table 14
Significant Difference on the Level of Agreement of the Participants on the Factors Contributing to the Safety Culture When Group According to Specialization

VARIABLES	SPECIALIZATION	N	MEDIAN	MEAN RANK	H	SIG	DECISION
1. Functional Suitability	MA31 A&P	20	3.333	24.7	1.95	0.378	Accept H_0
	MA32 REI	20	3.500	28.5			
	MA 33 S/M	10	3.167	21.1			
2. Performance Efficiency	MA31 A&P	20	3.000	24.3	1.73	0.422	Accept H_0
	MA32 REI	20	3.167	28.6			
	MA 33 S/M	10	3.167	21.8			
3. Usability	MA31 A&P	20	3.625	27.2	3.73	0.155	Accept H_0
	MA32 REI	20	3.625	27.6			
	MA 33 S/M	10	3.000	17.9			
4. Reliability	MA31 A&P	20	3.250	25.8	0.30	0.861	Accept H_0
	MA32 REI	20	3.125	26.3			
	MA 33 S/M	10	3.375	23.4			
5. Maintainability	MA31 A&P	20	3.167	25.8	0.14	0.931	Accept H_0
	MA32 REI	20	3.167	24.7			
	MA 33 S/M	10	3.333	26.6			

LEGEND: N = Population; H (Kruskal-Wallis H-Tab); Sig (P-Value)

The Kruskal-Wallis H-Test shows that there is no significant difference between the three groups of participants on the level of agreement with the proposed enhanced lightning alert system for Lufthansa Technik Philippines in terms of Functional Suitability (H=1.95, p=0.378); Performance Efficiency (H=1.73, p=0.442); Usability (H=3.73, p=0.155); Reliability (H=0.30, p=0.861) and Maintainability (H=0.14, p=0.931). Thus, the null hypothesis is accepted. There is no significant difference in the level of agreement in the proposed enhancement of the lightning alert system for Lufthansa Technik Philippines.

Participants common issues and concerns encountered in the current system during a lightning event in terms of Current System Personnel Experience

Table 15
Frequency Distribution of Current System Personnel Experience of the Participants

PARTICULARS	Frequency f	RANK
Unknown Procedures (Standard operating procedure during a lightning alert).	24	3
Modes of Receiving the Alert (Receiving text messages, calls, and messages from online applications).	44	1
Unknown Duration of the Alert (knowledge of when the signal is over and when it is safe to resume ground operations).	36	2
Unknown Location of the Evacuation Site (personnel is unaware of the proper and approved evacuation site).	14	5
Differences in Alert Types (personnel cannot distinguish between yellow and red alerts).	18	4

Table 15 presented the frequency distribution of the participants' common issues and concerns encountered in the current system during a lightning event in terms of Current System Personnel Experience.

An overall majority result on common issues and concerns encountered in the current system during lightning showed that the top three most ranking is the following:

1. Modes of Receiving the Alert (Receiving text messages, calls, and messages from online applications).
2. Unknown Duration of the Alert (knowledge of when the signal is over and when it is safe to resume ground operations).
3. Unknown Procedures (Standard operating procedure during a lightning alert).

The other common issues and concerns encountered in the current system during lightning:

1. Differences in Alert Types (personnel cannot distinguish between yellow and red alerts).
2. Unknown Location of the Evacuation Site (personnel is unaware of the proper and approved evacuation site).

The participants ranked the common issues and concerns they have encountered with the current lightning alert system of Lufthansa Technik Philippines (LTP), where the personnel working on the LTP ramp demonstrate difficulties in receiving the alert when a lightning event is in progress. During these lightning activities, the participants pointed out they lacked the knowledge to when to resume maintenance and ground operations together and were unaware of the standard operating procedures. In addition, personnel cannot differentiate between alert types, and lastly, personnel are unaware of the proper and authorized evacuation site. The participant's response to the common issues indicates that, despite efforts to reduce the risk of lightning strikes, personnel have limited knowledge of the proper procedures and rely on instinct to protect themselves from lightning events. Perceptions of the correct lightning warning system, according to Ndlena (2021), are used to help people in the community prepare for and minimize the risk of lightning strikes and to help reduce their vulnerability to danger (e.g., by taking shelter indoors). An alert system is the set of capacities to generate and disseminate meaningful alert information to assist groups in preparing for natural hazards.

Proposed Enhancement of the Lightning Alert System

Table 16
Frequency Distribution of Proposed Enhancement of the Lightning Alert System of the Participants

PARTICULARS	Frequency f	RANK
Visual Aids and infographic materials that depict the new system installed in critical locations.	28	3
SMS Texts and Mobile chat applications will be added to the notification process to increase the situational awareness of the personnel working on the ramp during a lightning event.	33	1
Countdown to when the operation can resume will be added in the alert notification.	19	5
Locations of areas for evacuation will be disseminated to all maintenance personnel.	24	4
Maintenance personnel will receive an automated advisory regarding the lightning alert.	29	2

An overall majority result on common issues and concerns encountered in the current system during a lightning activity showed that the top three most ranking is the following:
1. SMS Texts and Mobile chat applications will be added to the notification process to increase the situational awareness of the personnel working on the ramp during a lightning event.

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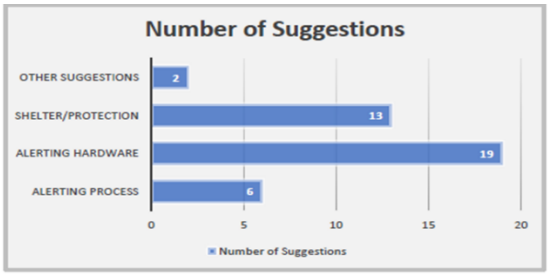
2. Maintenance personnel will receive an automated advisory regarding the lightning alert.
3. Visual Aids and infographic materials that depict the new system installed in critical locations.

The other common issues and concerns encountered in the current system during lightning:

1. Locations of areas for evacuation will be disseminated to all maintenance personnel.
2. The alert notification will add a countdown when the operation can resume.

Suggestions made to enhance a lightning alert system for a maintenance repair organization

Table 17
Number of Suggestions from the Participants for the Enhancement of the Lightning Alert for Lufthansa Technik Philippines



The participants' suggestions are classified as Alerting Process, Shelters/Protection, Alerting Hardware, and Other Suggestions. Data shows that alerting hardware ranks first with 19 suggestions, shelters/protection ranks second with 13 suggestions and alerting process ranks third with six suggestions.

The participants suggested that the alerting process with proper dissemination of the procedure for what to do in the event of lightning activity on the ramp and an improvement of alerting through the use of modern technologies, such as the automation of alerting

methods and utilization of the devices already installed to disseminate safety bulletins. In addition, suggestions were made by the participants regarding the installation of lightning alert hardware in every other bay to cover the entire ramp; devices such as sirens for aural warning and flashing beacons for visual warning; and a PA system to inform the personnel working in the ramp about the lightning activity status for redundancy purposes. In addition, the installation evacuation facilities are also equipped with lightning protection and communication devices. According to Islam (2019), lightning is a major weather phenomenon in Southeast Asia, where most affected areas are located. Lightning strikes cause damage to various industries, real estate, defense, and human fatalities. The existing ineffective lightning detection network is compelled to modify and enhance the system to fulfill the standards.

Summary of Findings

The experienced common issues and concerns of the participants are ranked in the following:

Common issues and concerns encountered in the existing lightning alert system.

1. Modes of Receiving the Alert (Receiving text messages, calls, and messages from online applications).
2. Unknown Duration of the Alert (knowing when the signal is over and when it is safe to resume ground operations).
3. Unknown Procedures (Standard operating procedure during a lightning alert).

Suggestions to enhance a lightning alert system for a maintenance repair organization.

An overall majority result on the proposed enhancement in the lightning alert system showed that the top three most ranking is the following:

1. SMS Texts and Mobile chat applications will be added to the notification process to increase the situational awareness of the personnel working on the ramp during a lightning event.
2. Maintenance personnel will receive an automated advisory regarding the lightning alert.
3. Visual Aids and infographic materials that depict the new system installed in critical locations.

The other common issues and concerns encountered in the current system during lightning:

1. Locations of areas for evacuation will be disseminated to all maintenance personnel.
2. The alert notification will add a countdown when the operation can resume.

The reiteration of the alerting process with proper dissemination of the procedure on what to do in case of lightning activity in the ramp with the enhancement of alerting via the utilization of modern technologies such as the automation of alerting methods and usage of the devices already installed to cascade safety bulletins. Repeated suggestions were also made regarding the installation of lightning alert hardware in every other bay to cover the entirety of the ramp; devices such as sirens for aural warning and flashing beacons for visual warning; together with a PA system to notify the personnel working in the ramp about the status of the lightning activity for redundancy purposes. In addition, the installation of evacuation facilities with lightning protection devices and communication instruments.

Conclusions

1. The participants were divided according to their skill to twenty (20) MA31 A&P – Airframe and Powerplant, twenty (20) MA32 REI – Radio, Electronics & Instruments, and ten (10) MA33 S/M – Structures. The majority of participants have been working at Lufthansa Technik Philippines (LTP) for less than 10 years.
2. The participants perception regarding the implementation of the lightning alert system in terms of Safety, Timeliness, Alert Notification, and Policies and Procedures are partially implemented only.
3. There was no significant difference in the participant's assessment of the level of implementation in terms of Safety, Timeliness, and Alert notification.

However, the criteria of Policies and Procedures the hypothesis is rejected, thus there is a significant difference in the level of implementation in the criteria of Policies and Procedures.

4. Overall, the participants were satisfied with the level of agreement in the proposed enhanced

lightning alert system in terms of functional suitability, performance efficiency, usability, reliability, and maintainability.

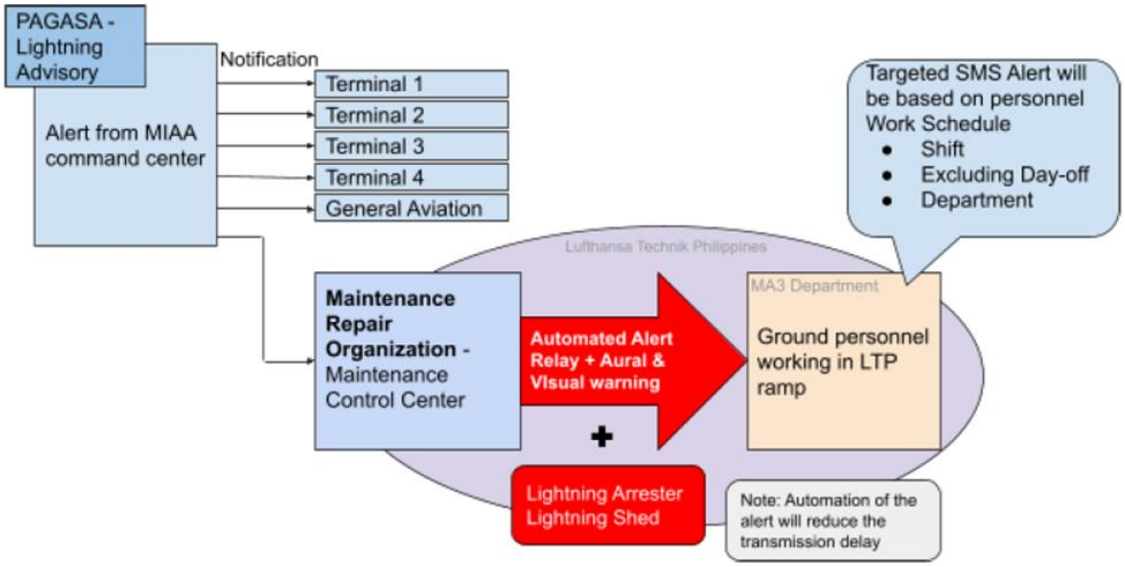
5. There is no significant difference between the three groups of participants on the level of agreement with the proposed enhanced lightning alert system for Lufthansa Technik Philippines in terms of functional suitability, performance efficiency, usability, reliability, and maintainability. Furthermore, as shown in table 17, the data concludes that the participants see the proposed enhancement as strongly agree.
6. The participant's perception of the most common issues and concerns encountered in the existing lightning alert system is as follows Modes of Receiving the Alert; Unknown Duration of the Alert; Unknown Procedures; Differences in Alert Types; Unknown Location of the Evacuation Site.
7. Based on the study's findings the participants strongly suggested the automation of the alerting system for maintenance personnel, additional visual and oral warning system, installation of evacuation shelters, and detailed policies and procedures that will guide the maintenance personnel during a lightning event.

Recommendations

1. The future researchers intentionally select more tenured participants, as lightning strikes are infrequent and they have the most encounters with lightning occurrences. Moreover, tenured participants have a better understanding of the organization's safety guidelines, Policies, and Procedures.
2. Management should constantly strategize the proper implementation of the lightning alert system, as shown in figure 5, to elevate and improve the lightning alert system to reduce the risk of a lightning strike for maintenance personnel working in the LTP ramp.
3. The management should further strengthen the implementation level of the lightning alert system in which the policies and procedures are disseminated through multiple channels, including safety bulletins, flyers, read and sign, seminars, and specialized training.
4. The management should continuously incorporate new ideas and proposals that utilize modern public announcement systems that have reliable communication devices and lightning alert systems to safeguard its personnel effectively.
5. The management should consider the adaptation of the proposed enhancement of the lightning alert system
6. The management should improve the lightning alerting process to automated warning and evacuation to the affected personnel. For redundancy, an aural and visual warning system should be strategically installed in critical areas of the affected workplace.
7. Redesign the lightning alert system to streamline the alert flow and to make it so that warning reaches the affected maintenance personnel more quickly.

PROPOSED LIGHTNING ALERT SYSTEM

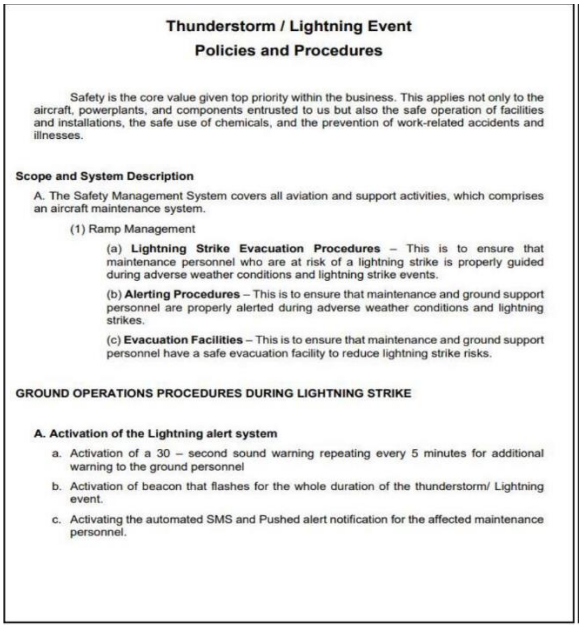
Figure 1
Proposed Enhancement of the Lightning Alert System for Lufthansa Technik Philippines



Shown in figure 1 is the proposed enhancement of the lightning alert system flow for Lufthansa Technik Philippines where:

1. Lightning Advisory from PAGASA is sent to Manila International Airport Authority Command Center.
2. Manila International Airport Authority – Command Center (MIAACC) will send the alert to apron management services in different departments (Terminal 1, Terminal 2, Terminal 3, Terminal 4, General Aviation, Maintenance Repair Organizations, and other airport occupants).
3. Alert received from MIAACC - LTP Lufthansa Technik Philippines - Maintenance Control Center (LTP-MCC) duty managers will disseminate the alert via a trigger installed in the LTP-MCC office that will send an automated push notification and a targeted SMS alert to the personnel working in the ramp that is based on their work shift schedule. It will also trigger an Aural warning installed in the ramp that will ring for 5 minutes, signaling the start of the lightning alert. In parallel, a Visual alert will flash for the whole duration of the alert.
4. Upon receiving the alert, the personnel working on the ramp will halt maintenance operations "work-stoppage" and seek shelter for evacuation. Alert received from MIAACC - LTP Lufthansa Technik Philippines - Maintenance Control Center (LTP-MCC) duty managers will disseminate the alert via a trigger installed in the LTP-MCC office that will send a push notification and a targeted SMS alert to the personnel working in the ramp that is based on their work shift schedule. It will also trigger an Aural warning installed in the ramp that will ring for 5 minutes, signaling the start of the lightning alert. In parallel, a Visual alert will flash for the whole duration of the alert.
5. Upon receiving the alert, the personnel working on the ramp will halt maintenance operations "work-stoppage" and seek shelter for evacuation, to which shelters are grounded and equipped with protection devices that create a protective function and redirects lightning into the ground.

Proposed Lightning Alert System Policies and Procedures
Figure 2



Thunderstorm / Lightning Event
Policies and Procedures

Safety is the core value given top priority within the business. This applies not only to the aircraft, powerplants, and components entrusted to us but also the safe operation of facilities and installations, the safe use of chemicals, and the prevention of work-related accidents and illnesses.

Scope and System Description

A. The Safety Management System covers all aviation and support activities, which comprises an aircraft maintenance system.

(1) Ramp Management

(a) **Lightning Strike Evacuation Procedures** – This is to ensure that maintenance personnel who are at risk of a lightning strike is properly guided during adverse weather conditions and lightning strike events.

(b) **Alerting Procedures** – This is to ensure that maintenance and ground support personnel are properly alerted during adverse weather conditions and lightning strikes.

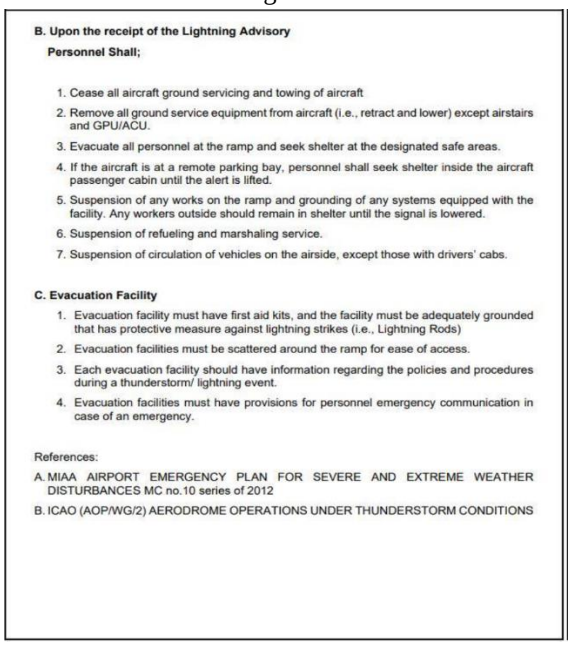
(c) **Evacuation Facilities** – This is to ensure that maintenance and ground support personnel have a safe evacuation facility to reduce lightning strike risks.

GROUND OPERATIONS PROCEDURES DURING LIGHTNING STRIKE

A. Activation of the Lightning alert system

a. Activation of a 30 – second sound warning repeating every 5 minutes for additional warning to the ground personnel
b. Activation of beacon that flashes for the whole duration of the thunderstorm/ Lightning event.
c. Activating the automated SMS and Pushed alert notification for the affected maintenance personnel.

Figure 3



B. Upon the receipt of the Lightning Advisory
Personnel Shall;

1. Cease all aircraft ground servicing and towing of aircraft
2. Remove all ground service equipment from aircraft (i.e., retract and lower) except airstairs and GPU/ACU.
3. Evacuate all personnel at the ramp and seek shelter at the designated safe areas.
4. If the aircraft is at a remote parking bay, personnel shall seek shelter inside the aircraft passenger cabin until the alert is lifted.
5. Suspension of any works on the ramp and grounding of any systems equipped with the facility. Any workers outside should remain in shelter until the signal is lowered.
6. Suspension of refueling and marshaling service.
7. Suspension of circulation of vehicles on the airside, except those with drivers' cabs.

C. Evacuation Facility

1. Evacuation facility must have first aid kits, and the facility must be adequately grounded that has protective measure against lightning strikes (i.e., Lightning Rods)
2. Evacuation facilities must be scattered around the ramp for ease of access.
3. Each evacuation facility should have information regarding the policies and procedures during a thunderstorm/ lightning event.
4. Evacuation facilities must have provisions for personnel emergency communication in case of an emergency.

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ACKNOWLEDGEMENT

To our dear panelists, Dr. Estrella E. Yago, Dr. Leo Mendel D. Rosario, Dr. Eleonor H. Calayag, Dr. Leonardo C. Medina, Jr., And especially Dr. Roderick C. Santiago, Our Professorial Lecturer in the MEAM 615 class and the chairman of the thesis panel of examiners and the designated acting dean for the Institute of Graduate Studies, who always inspired his candidates and pursued the project with unwavering encouragement and remarkable diligence;

I express my sincere gratitude to my research adviser, Dr. Alfredo Joson, for providing me with the opportunity to conduct research and for invaluable guidance throughout this research. His dynamism, vision, sincerity, and motivation have inspired me tremendously. He has instructed me in the methodology for conducting research and presenting it as clearly as possible. Working under his direction was a great honor and privilege. I appreciate what he has provided and am thankful for his friendliness, compassion, and humor.

To my Managers Mr. Gideon Pascual and Mr. June Del Rosario, Plane Crew Chiefs (Sir Arnie, Sir Dennis, Sir Geffrey, Sir Michael, and Sir Simon), seniors, and colleagues, for their views, suggestions, knowledge, cooperation, and especially patience, to which I owe a deep debt of gratitude.

Finally, I would like to thank my family and friends for their inspiration, unwavering support, and belief in my ability to accomplish this feat. Without your prayers, genuine love, and assistance, I would never have finished this thesis

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