The Role of People in Continuing Airworthiness: A Case Study Based on the Royal Thai Air Force

B. Ratchaneepun, N.S. Bardell

***Abstract*—**It is recognized that people are the main drivers in almost all the processes that affect airworthiness assurance. This is especially true in the area of aircraft maintenance, which is an essential part of continuing airworthiness. This work investigates what impact English language proficiency, the intersection of the military and Thai cultures, and the lack of initial and continuing human factors training have on the work performance of maintenance personnel in the Royal Thai Air Force (RTAF). A quantitative research method based on a cross-sectional survey was used to gather data about these three key aspects of "people" in a military airworthiness environment. 30 questions were developed addressing the crucial topics of English language proficiency, impact of culture, and human factors training. The officers and the non-commissioned officers (NCOs) who work for the Aeronautical Engineering Divisions in the RTAF comprised the survey participants. The survey data were analysed to support various hypotheses by using a *t*-test method. English competency in the RTAF is very important since all of the service manuals for Thai military aircraft are written in English. Without such competency, it is difficult for maintenance staff to perform tasks and correctly interpret the relevant maintenance manual instructions; any misunderstandings could lead to potential accidents. The survey results showed that the officers appreciated the importance of this more than the NCOs, who are the people actually doing the hands-on maintenance work. Military culture focuses on the success of a given mission, and leverages the power distance between the lower and higher ranks. In Thai society, a power distance also exists between younger and older citizens. In the RTAF, such a combination tends to inhibit a just reporting culture and hence hinders safety. The survey results confirmed this, showing that the older people and higher ranks involved with RTAF aircraft maintenance believe that the workplace has a positive safety culture and climate, whereas the younger people and lower ranks think the opposite. The final area of consideration concerned human factors training and non-technical skills training. The survey revealed that those participants who had previously attended such courses appreciated its value and were aware of its benefits in daily life. However, currently there is no regulation in the RTAF to mandate recurrent training to maintain such knowledge and skills. The findings from this work suggest that the people involved in assuring the continuing airworthiness of the RTAF would benefit from: (i) more rigorous requirements and standards in the recruitment, initial training and continuation training regarding English competence; (ii) the development of a strong safety culture that exploits the uniqueness of both the military culture and the Thai culture; and (iii) providing more initial and recurrent training in human factors and non-technical skills.

***Keywords*—**Aircraft maintenance, continuing airworthiness, military culture, people, Royal Thai Air Force.

B. Ratchaneepun was a Masters student at RMIT University, Melbourne, Australia. He is currently serving in the RTAF with the rank of Flight Lieutenant (phone +66 9 6569 2916; e-mail: maximus.bushido@gmail.com)

N.S.Bardell is a Senior Lecturer in Aviation in RMIT University, Melbourne, Australia (phone: +61 3 9925 8066; e-mail: nick.bardell@ rmit.edu.au).

I. Introduction

AIRWORTHINESS is generally known as one of the aspects to assure flight safety. People are one of the key factors which run airworthiness processes. The importance of people in delivering airworthiness is clearly illustrated [1] by the events surrounding the fatal accident of the UK Royal Air Force Nimrod XV230 in 2006 during a routine reconnaissance mission in Southern Afghanistan. In this case there were many factors involving people that contributed to the accident that cost the lives of 14 British servicemen. Following the RAF Board of Inquiry, an independent review was conducted by Sir Charles Haddon-Cave [2] which is now considered to be one of the classic case studies of military airworthiness. As a result of this review, the UK military airworthiness system was completely overhauled (see [3] for details) with emphasis placed on the following four key principles proposed by Haddon-Cave [2]:

- Leadership: "There must be strong leadership from the very top, demanding and demonstrating by example active and constant commitment to safety and airworthiness as overriding priorities."
- Independence: "There must be thorough independence throughout the regulatory regime, in particular in the setting of safety and airworthiness policy, regulation, audition and enforcement."
- People (not just process and paper): "There must be a much greater focus on people in the delivery of high standards of safety and airworthiness (and not just on process and paper)."
- Simplicity: "Regulatory structures, processes and rules must be as simple and straightforward as possible so that everyone can understand them."

This paper focuses the third of these key principles, namely, the role of people in delivering continuing airworthiness and high standards of safety.

Continuing airworthiness is defined by ICAO [4] as "the set of processes by which an aircraft, engine, propeller or part complies with the applicable airworthiness requirements and remains in a condition for safe operation throughout its operating life". It is essentially an ongoing maintenance strategy that helps stakeholders have confidence in the instantaneous state of safety and integrity of a given aircraft.

It is clear that people are the main driver in almost all the processes concerned with airworthiness, including the design, manufacture, maintenance, and operation of an air vehicle. Haddon-Cave [2] goes on to say that such people should be

well-trained and competent to do their jobs. This sentiment is echoed by the Australian Defence Force [5], which asserts that airworthiness processes should be conducted by "competent and authorised individuals, who are acting as members of an approved organisation and whose work is both certified as correct and accepted by Defence".

The RTAF is the military air operator in Thailand, and has the responsibility to ensure that its aircraft can operate safely and effectively. Since Thailand does not produce its own military aircraft, all the types it currently operates are sourced from overseas, as shown in Appendix A, and all the maintenance manuals, flight manuals, and instructions for continuing airworthiness are written in English.

Currently, the RTAF has no independent military authority to oversee and regulate its airworthiness processes, and no regulatory suite for managing initial or continuing airworthiness. The guidance used in the process of continuing airworthiness is simply a manual [6] without any regulatory oversight.

The people working in the aircraft maintenance sector in the RTAF are the officers and the NCOs who have completed their training at one of Thailand's two military training institutions - the Air Technical Training School or the Military Technical Training School. These maintenance personnel are responsible for ensuring that the RTAF military aircraft can perform their designated missions safely and effectively. However, the authors contend that the ability of these people to do their jobs properly is compromised to some extent by three main factors: (i) inadequate English proficiency, (ii) the impact of workplace and national culture, and (iii) the lack of human factors training. This paper seeks to quantify the impact of these three issues on the performance of the maintenance personnel in the Aeronautical Engineering Divisions in the RTAF's sub-organizations, and to provide some recommendations for improvement.

II. Background and Literature Review

A. Language (English) Difficulties in Aircraft Maintenance

Communication is the means by which information is shared and transferred from a sender to a receiver in either a verbal (spoken communication) or non-verbal (written communication) form [7]. Regarding a basic communication framework, communications use messages, containing details, like language, to transfer the information to the receivers [8]. The language expresses and explains the meaning of the data.

From a maintenance viewpoint, the documents provided by the design organizations or manufacturers of military and civil aircraft are generally written in English [9]. For instance, the CT-4E military training aircraft used by RTAF is manufactured in New Zealand where English is the main language. Hence, all the supporting documents are written in English. Drury and Ma [10] found that errors in maintenance processes can occur from both verbal and non-verbal communication; in the latter case, maintenance technicians may sometimes misunderstand the meaning of certain words in the documents [10]. Shukri et al. [11] similarly found that misinterpreting the data can lead to a misunderstanding of the process required to maintain an aircraft resulting in a reduced level of safety and quality. It is also understood [12] that the thinking behind one word can mean different things in different languages. Therefore, something as simple as a linguistic failure due to miscommunication may ultimately lead to an aircraft incident or accident. Errors can also result from other factors such as unclear, incorrect, and insufficient information, insufficient time to complete the task, and absence of diagrams in the documents which would otherwise aid the end-user's understanding of the words and sentences [13].

B. The Impact of Culture on Safety

There are many meanings of the word "culture". One definition [14] is "the sharing of beliefs, values, norms and goals among the members in that society". Kluckhohn [15] explains that culture provides the bonds that allow people in one location to share the same behavior and attitude. From a safety perspective, a positive culture can be developed which encourages the members of a society to act safely [16]. Rachman [17] found that cultural factors play an important role in safety, especially when promoting a safety culture and climate, such as a safety management system, to enhance aviation safety. This accords with Haddon-Cave's first key principle [2], namely, "There must be strong leadership from the very top, demanding and demonstrating by example active and constant commitment to safety and airworthiness as overriding priorities."

Military culture is one of the unique corporate cultures, typified by the primary goal of mission success [17]. The military "can-do" culture is often cited as a reason why safety gets compromised during operations [18]. Devries et al. [19] point out that the difference between the ranks, which is created to support the chain-of-command, can affect the perception at each level and generate its own sub-culture in the military community. Significantly, this feature generates the power distance, defined as the gap in authority between powerful, and less powerful, people, within the organization. Many military incidents and accidents have resulted from a lack of bottom-up communication, where people of higher rank have not listened to their subordinates, or where people of lower rank have been afraid to raise an issue with their superiors [20].

National culture refers to the beliefs and goals of a national or ethnic group, and it is well documented that people from different national cultures can perceive safety differently [17]. For example, [21] reports that pilots in Western airlines believe that safety is the number one priority, and reporting a hazard can promote a good safety culture, whereas in Eastern society, the power distance between the junior and the senior pilot can hinder a safety culture. Helmreich and Merrit [22] claim that such a power distance generates difficulties for the juniors to challenge and question the actions of their seniors, especially in emergency situations. In the context of the current work, 'Thai society' is also considered to be a high power distance society [23]. Hence the intersection of Thai

national culture and the military culture in the RTAF generates a very high power distance environment in which the younger and more junior ranks have to pay respect and show deference to their elders who generally hold more senior ranks.

C. Human Factors Training for Aircraft Maintenance Personnel

Human factor issues are especially relevant to the aviation industry, where human error remains the primary cause of aircraft incidents and accidents - a few examples are shown in Table I. Therefore, it is undeniable with the significance in human factors training which has been widely accepted as an effective solution to reduce the possibility of human errors. A high-risk organization like aircraft maintenance organizations, which their activities can affect people safety, should provide their employees with initial and refresher training.

TABLE I
A SELECTION OF ACCIDENTS ARISING FROM HUMAN ERROR IN AIRCRAFT MAINTENANCE, ADAPTED FROM [24]

Aircraft / Airline	Location	Year	Accident Causes
Japan Airlines Boeing 747	North-west of Tokyo	1985	Failure of part installation and inspection.
Aloha Airlines Boeing 737	En-route between Hilo and Honolulu	1988	Fault in the corrosion and fatigue inspection.
British Airways BAC-111	UK	1990	Using the wrong type of bolts to secure the windshield.
RAN Westland WS-61 Sea King helicopter	Nias Island, Indonesia	2005	Failure of the aircraft's flight control systems, resulting from a series of errors, and a general practice of poor maintenance on the aircraft.
RAF Nimrod MR2 XV-230	Afghanistan	2006	Ageing aircraft, poor maintenance regime, flawed safety case.

Gramopadhye and Drury [25] state that maintenance tasks contribute to the safety and reliability of the aircraft used in both civil and military operations. As a result, human errors in the aircraft maintenance process should be highlighted to prevent unpredictable outcomes. According to the Australian Defence Aviation Safety Regulations (DASR) Part 145.A.30(e) [26], Personnel requirement: "In addition to the necessary expertise related to the job function, competence must include an understanding of the application of human factors and human performance issues appropriate to that person's function in the organization". The workforce of an Approved Maintenance Organisation (AMO) is also required to understand human factors. AMC145.A.35(d) in DASR Part 145 states that "Continuation training should be of sufficient duration in each two-year period to meet the intent of DASR Part 145.A.35 (d)". DASR Part 145.A35(d) itself states "Continuation training is a two-way process to ensure that certifying staff remain current in terms of procedures, human factors and technical knowledge" [26]. Hence, continuation training places great emphasis on the importance of human factors, which is considered essential in aircraft maintenance processes.

The Australian Defence Aviation Safety Authority (DASA) [27] suggests that the purpose of human factors training in a maintenance training program is to reduce the possibility of any error in the man/machine interface and reduce the risks caused by organizational factors. Human factors training for maintenance workers is as necessary as that for flying or air traffic control tasks. Chang and Wang [28] point out that human factors training plays an essential role in decreasing the possibility of human error by fostering robust attitudes, knowledge, and skills. Hence, human factors should be included in a maintenance curriculum. Indeed, [29] argues that from a human perspective, "maintenance personnel have more in common with doctors or surgeons than pilots".

Non-technical skills (NTS), such as teamwork, communication, and situational awareness are considered as important sub-topics in human factors [7]. Taylor [30] claims that an individual error is not necessarily the main contribution to an accident; other factors, like teamwork and organizational culture, may also play a part. Irwin et al. [31] state that aircraft maintenance, which is considered to be a high-risk task, requires training in NTS to enhance personal performance and safety in operations. This is because NTS integrate both the cognitive and social perspectives, and this can help mitigate human error in aircraft maintenance [32]. However, in the RTAF there is no set of regulations or any document specifying initial and recurrent human factors training; it is not contained in the curriculum for initial maintenance training in any of the military training institutions. Instead, once maintenance personnel graduate from their training academy and join their active wing or squadron, they are offered, along with the rest of the organization, a one- or two-day bespoke course in human factors. However, as the survey reveals in Table II, there are many participants who never attend such training.

III. METHODOLOGY

A. Survey Design

This research used a quantitative method based on a cross-sectional survey to gather data about some key aspects of "people" in an airworthiness environment. 30 statements were developed and categorized into three sections comprising ten statements each: (i) the use of English in aircraft maintenance, (ii) cultural influences in the workplace, and (iii) human factors training, see Appendix B. Each respondent was asked to provide a level of agreement with each statement utilizing a five-point Likert scale [33] arranged as: 1. "Strongly disagree"; 2. "Disagree"; 3. "Neutral"; 4. "Agree"; and 5. "Strongly agree".

The participants targeted for this survey were officers and NCOs who work for the Aeronautical Engineering Divisions within two different RTAF air operators (for confidentiality reasons the actual squadrons involved in this survey cannot be identified here). The types of aircraft in their service are the Pacific Aerospace Corporation (PAC) CT-4E, the Pilatus PC-9, the Diamond DA-42 and the Basler BT 67, which are manufactured by companies from New Zealand, Switzerland, Austria, and the USA respectively. All maintenance

documentation is supplied in English, and this was a major consideration in selecting these two particular groups from all the other air operators in the RTAF.

The participants were invited by email to voluntarily and anonymously participate in this research study, and the survey itself was distributed using a Google form. Participants were asked to provide some personal information like rank, age, the number of years they had spent working in aircraft maintenance, and whether or not they had participated in any courses related to human factors. From a modelling point of view such demographic information permits subsequent between-group comparisons. The 20-minute survey was conducted during the month of September 2019.

B. Hypotheses

There are five null-hypotheses (H_0) presented here which were influenced from the literature and the first author's practical service experience. These are intended to furnish answers to the main research questions discussed in Section I:

- Hypothesis 1: The officers and the NCOs are just as likely to have the same level of competency when it comes to reading aircraft maintenance manuals in English.
- Hypothesis 2: The officers and the NCOs have the same attitude towards English skills, like writing and reading, knowing both are essential for understanding aircraft maintenance tasks.
- Hypothesis 3: The organizational (military) culture affects both the officers and the NCOs' equally regarding their perception toward safety.
- Hypothesis 4: The older participants (more than 40 years old) are more affected by the national culture, and hence approach safety matters more diligently, than the younger participants (18-40 years old).
- Hypothesis 5: The officers or the NCOs who have previously participated in human factors training have a better knowledge and more positive attitude towards such training than those who have never attended this type of training.

C. Data Analysis

The built-in statistical functions within Microsoft Excel 2016 were used to perform the data analysis [34]. The results from the survey, showing the percentage of agreement, are presented as a bar chart [35], [36]. To determine whether or not the difference between the mean value found from the responses of two comparison groups reflects a "real" difference in the population, a *t*-test assuming unequal variances was utilized [36], [37]. The standard significance level of 0.05 (that is, 95% confidence) was used to determine whether the results were statistically significant. If the significance level exceeds 0.05, which indicates a confidence level less than 95%, the null hypothesis (H_0) was accepted; otherwise, it was rejected, and the alternative hypothesis (H_1) was accepted by comparing the mean value between the two groups of data. Since the research hypotheses presented herein do not signify the direction of interaction or difference, it is appropriate to use a two-tailed *t*-test when determining the level of significance.

D. Limitations

Three basic limitations occurred in the survey. Firstly, the authors could not be certain they had obtained accurate data from the survey, given the cultural factors present in the military community and Thai society [38]. Some participants may have been reluctant to provide factual answers simply because they did not want to be seen as overly negative, and some may have answered in a particular manner bowing to peer pressure. Secondly, some participants may have found it difficult to distinguish between the levels of intensity required between adjacent criteria [39], such as "Strongly Agree" compared with "Agree". Finally, as in all surveys, a larger sample size would have provided a more robust data set.

IV. Quantitative Analysis and Results

A. Survey Respondents

The total number of officers and NCOs from the aircraft maintenance divisions in the two sub-organisations of the RTAF who responded to the survey amounted to 191 participants, as shown in Table II.

TABLE II
SUMMARY OF THE RESPONDENTS' DEMOGRAPHY

	Respondent	Percentage (%)
Rank		
Officer	30	16
NCO	161	84
Age		
18-40 years	115	60
> 40 years	76	40
Experience		
< 5 years	50	26
> 5 years, but < 15 years	55	29
> 15 years	86	45
Human Factors Course		
Yes (1 time)	59	31
Yes (2-4 times)	69	36
Yes (More than 5 times)	13	7
Never	50	26

B. English Competency

To determine their ability to use English in the aircraft maintenance processes, the group of participants was divided by rank (officer and NCO). The first hypothesis was tested using responses from the first five questions of the language section in Appendix B. These responses were averaged to obtain a single set of values for the officers and the NCOs.

The distribution of responses from all the participants can be seen in Fig. 1. This shows that the majority of the officers agree that their English competence is sufficiently good to allow them to conduct their maintenance tasks confidently. Meanwhile, the majority of the NCOs are less certain about their language competence.

Table III shows the hypothesis testing results. The two-tailed test has a confidence level value of 99.06%, which exceeds the 95% level, and hence the null hypothesis must be rejected. Table III also shows that the mean for the officers is higher than that for the NCOs, indicating the officers are more confident with their levels of English competency in aircraft

maintenance than the NCOs.

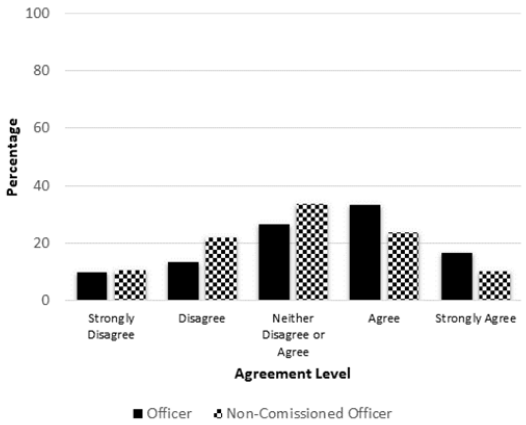

Fig. 1 Confidence using English in an aircraft maintenance environment

TABLE III
SUMMARY OF ENGLISH COMPETENCE RESULTS

Statistic	Officer	NCO
Mean	3.346	3.014
Variance	0.179	0.295
Observations	30	161
Hypothesized Mean Difference	0	
df	49	
t Stat	3.7697	
p(T <= t) two-tail	0.0004	
t Critical two-tail	2.0096	

C. The Importance of English in Aircraft Maintenance Work

The belief in the importance of English in aircraft maintenance was compared between the officers and the NCOs. The second hypothesis was tested using responses from the latter five questions regarding the proficiency in English in Appendix B. The responses to these last five questions were also averaged to obtain a single set of values for the officers and the NCOs.

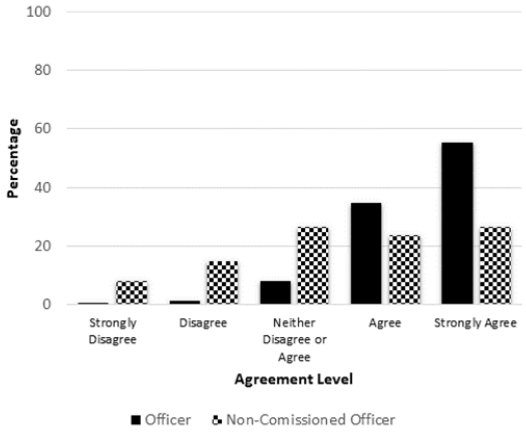

Fig. 2 Attitude towards the importance of English in an aircraft maintenance environment

Fig. 2 shows the distribution of the levels of agreement about how important it is to have a good working knowledge of English in the aircraft maintenance process. Both the officers and the NCOs exhibit a strong belief in the benefits of English proficiency. However, around 50% of the NCOs fall under the disagree or neutral categories regarding the necessity of developing such skills.

The results of the attitude toward the importance of English proficiency can be seen in Table IV. A *t*-test indicates that the two-tailed test for this sample exceeds the 95% confidence level, and thus the null hypothesis is rejected, and the mean can be used for comparison purposes. The mean for the officers, at 4.43, is greater than the mean for the NCOs, at 3.54, thus indicating that the officers believe more in the importance of developing a good attitude and proficiency towards English in aircraft maintenance than the NCOs.

TABLE IV
SUMMARY OF ATTITUDE TOWARDS ENGLISH PROFICIENCY

Statistic	Officer	NCO
Mean	4.426	3.538
Variance	0.143	1.200
Observations	30	161
Hypothesized Mean Difference	0	
df	132	
t Stat	8.0429	
p(T <= t) two-tail	4.4095×10^{-13}	
t Critical two-tail	1.9781	

D. The Influence of Military Culture on Safety

To evaluate the maintenance personnel's perception of the organizational safety culture and climate, this analysis considered the influence of both military and Thai national cultures. The former is discussed here; the latter is presented in Subsection *E*. The impact of military culture on the workforce's perception of organizational safety is based on a comparison of the responses from officers and NCOs. All ten questions in the cultural section of the survey (Appendix B) were utilized to determine the validity of hypothesis 3; the responses to all ten questions were averaged to obtain a single set of values for the officers and NCOs.

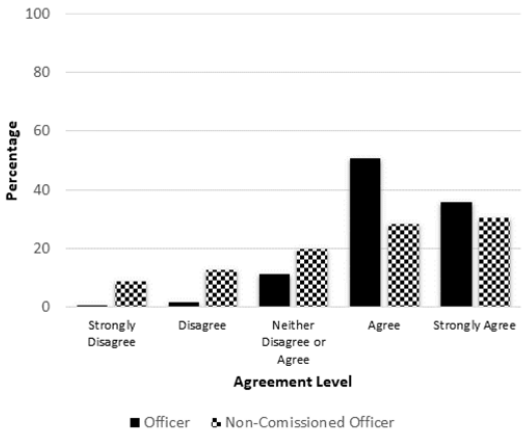

Fig. 3 Impact of military culture on safety culture

The distribution of the agreement level in the effectiveness of the military safety culture and climate is illustrated in Fig. 3. The majority of both the officers and the NCOs confidently agree that the military safety culture and climate are effective. However, around 40% of the NCOs fall under the disagree or neutral categories regarding the safety culture effectiveness.

TABLE V
THE EFFECT OF MILITARY CULTURE ON THE OVERALL SAFETY CLIMATE

Statistic	Officer	NCO
Mean	4.190	3.584
Variance	0.226	1.188
Observations	30	161
Hypothesized Mean Difference	0	
df	97	
t Stat	4.9602	
p(T <= t) two-tail	3.00003×10^{-6}	
t Critical two-tail	1.9847	

The results for the impact of military culture on the overall safety climate are shown in Table V. The confidence level in the two-tailed test is almost 100%, which exceeds the 95% confidence level, and thus the null hypothesis is rejected. The mean for the officers, at 4.19, is greater than the mean for the NCOs, at 3.58, suggesting that the officers believe more in the effectiveness of the military safety culture and climate than the NCOs.

E. The Influence of Thai National Culture on Safety

The second part of the investigation into the workforce's perception of organisational safety culture considers the influence of Thai national culture – this can be assessed by considering the survey responses obtained from older and younger participants. The respondents were divided into two groups by age (18 years to less than 40 years, and more than 40 years).

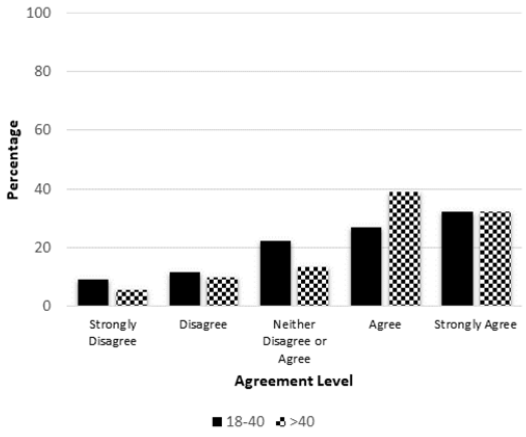

Fig. 4 Impact of Thai national culture on safety culture

All the questions in the cultural section of the survey (Appendix B, Table IX) were utilised to verify hypothesis 4, and were averaged to obtain a single set of values for the younger and older participants.

Fig. 4 shows the levels of agreement found from both age groups. This suggests that the majority of people from both age groups have confidence in the organisational safety culture. It is interesting to note from the disagree or neutral categories that the younger people (all ranks) are noticeably less sure or confident in the effectiveness of the safety culture than the older people.

Table VI shows the *t*-test results used to determine the level of agreement in the effectiveness of the organisational safety culture. The two-tailed test has a 90.3% confidence level, indicating the null hypothesis can be accepted. From this, it can be concluded that the younger maintenance people are impacted more by the Thai culture than the older maintenance people as far as organisational safety culture is concerned.

TABLE VI
THE EFFECT OF THAI NATIONAL CULTURE ON THE OVERALL SAFETY CLIMATE

Statistic	18–40 years	> 40 years
Mean	3.580	3.830
Variance	1.154	0.952
Observations	115	76
Hypothesized Mean Difference	0	
df	171	
t Stat	-1.6660	
p(T <= t) two-tail	0.0976	
t Critical two-tail	1.9847	

F. Human Factors Training

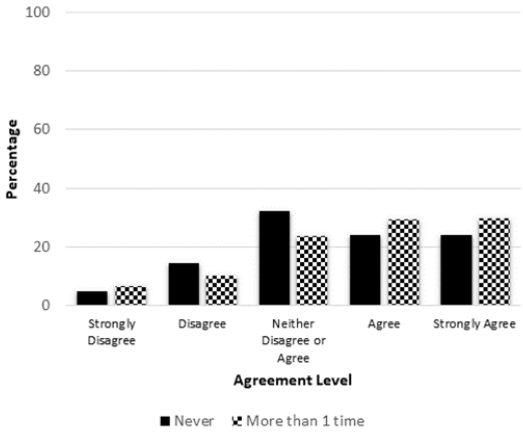

Fig. 5 Attendance at human factors training

The last hypothesis is that those participants who have previously attended human factors training should have more understanding and a better attitude than those who have never taken such courses. Therefore, the participants were divided into those who had, and those who had not, attended such courses. The distribution for hypothesis 5 can be seen in Fig. 5. Of the 191 respondents, 50 rather worryingly admitted to never having attended any human factors training, whilst the remaining 141 had attended at least one session. Approximately 60% of those who had never participated in human factors training had little confidence in understanding the importance of this training, and did not appreciate its value in helping to prevent human error at work. On the other hand, more than half of the other group demonstrated a good

comprehension of human factors and NTS and understood how it assisted them in their daily routine work.

The results of a *t*-test for this hypothesis are shown in Table VII. This indicates that the two-tailed test exhibits a confidence level of 80.3%, which is less than the 95% confidence level, and is considered statistically significant. Hence, the null hypothesis was accepted, that is, those personnel who had previously participated in human factors training have a good understanding and more positive attitude towards the importance of such soft skills in everyday working life.

TABLE VII
THE IMPORTANCE OF HUMAN FACTORS TRAINING

Statistic	Previously attended	Never attended
Mean	3.653	3.474
Variance	0.857	0.638
Observations	141	50
Hypothesized Mean Difference	0	
df	99	
t Stat	1.3002	
p(T <= t) two-tail	0.1967	
t Critical two-tail	1.9842	

V. DISCUSSION

A. Language

Most of the world's aircraft manufacturers use English as the *lingua franca* of their aircraft maintenance manuals [9]. Hence anybody involved in aircraft maintenance cannot avoid being faced with English in their daily work. A maintenance workforce is hence expected to have adequate English competency to interpret and understand the meaning conveyed by the manuals, especially the NCOs who actually perform the hands-on maintenance tasks. Therefore, it is essential that the people in the RTAF aircraft maintenance process are competent using English, and demonstrate a positive attitude toward this language.

The results from this study (see Sections IV *B* and *C*) indicate that the officers are more confident with English than the NCOs, yet ironically it is the NCOs who are doing the hands-on work and who have the greater need to understand and interpret maintenance instructions in English. The NCO's lower level of English competence could adversely affect their ability to maintain the aircraft properly, and hence impact on the aircraft's airworthiness, as pointed out by [11] and [9]. The majority of officers feel that English is essential and necessary for the aircraft maintenance process, while the NCOs think differently. Rajprasit et al. [40] point out that the Thai education system does not specifically focus on English - it is not an official second language - and as a consequence many maintenance personnel feel that English language skills are less important than technical skills. This attitude can hinder the willingness of such people to enhance their personal competence in English. To overcome this obstacle, the RTAF should firstly recognize that a level of resistance to linguistic improvement exists within maintenance circles, and then provides the necessary language support to the current NCOs who are the main workforce delivering aircraft maintenance. For future recruits, the required level and standard in English proficiency should be included as a part of the recruitment pre-requisites [41]. Such pre-requirements can be used to screen applicants and thus raise the standard of English language competence of the people who are going to be involved in the hands-on maintenance tasks. In addition, the use of technical English content should be contained in any training curriculum in the same way that it is in civil aviation [8]. It must be emphasised to trainees that English language training is just as important as their technical training; only success in both will allow a trainee to successfully complete his/her apprenticeship.

Shawcross [41] goes on to suggest that some level of regulatory oversight can help reinforce the requirement to develop and maintain English competency. For example, DASR Part 66 [42] specifies certain minimum requirements for Australian RAAF personnel to hold and retain a military aircraft maintenance license (MAML). Whilst such airworthiness safety regulations currently do not exist within the Thai military, it is expected that in time the RTAF will introduce a requirement for its entire qualified maintenance staff to hold a MAML, and include specific regulations about the necessary levels of English competence required.

B. Culture

This research focuses on both military and Thai culture, as discussed in Sections IV *D* and *E*. The expectation is that organisational influences will impact all service personnel while the national culture impacts adversely on the younger officers and NCOs. The results from this work support both premises. There are clear differences in the perceptions of the higher and the lower ranks in the RTAF - the officers have a more positive perception about organisational safety than the NCOs, despite both working in the same organisation. Furthermore, the results from the survey show that the older and more senior people involved in RTAF aircraft maintenance believe that the workplace has a relatively sound safety culture and climate. On the other hand, the younger officers and NCOs think differently. It is evident the RTAF's personnel are affected directly by the influence of both military culture and the Thai national culture.

Wilson [43] states that military culture uses the chain-of-command to ensure subordinates follow orders from their commander without an argument. Hence, good leadership from the more senior officers and NCOs could play a significant role in creating a positive safety culture. DASA [44], following Haddon-Cave [2], asserts that the commander must express and communicate a genuine commitment toward safety, including allocating whatever resources are necessary to support safety activities and training. The command commitment can take the format of a non-punitive policy which empowers a just climate in the organisation, and fosters a fair and meaningful incident reporting system [45]. This will require a concerted effort from the senior ranks, but the dividends of safety assurance will more than pay for themselves.

Hallinger and Kantama [23] report that Thai people tend to adjust their individual beliefs and attitudes quite easily in order to fit in with the majority of the members of a group. In general, Thais also tend to avoid conflict and promote harmony, since this is a social norm. Therefore, if the majority of people in an organisation like the RTAF place a common value on safety, this will exert a very positive influence on everybody else in the organisation [46] and influence safety-conscious behaviour. Hence, it is quite feasible that these unique characters of military and Thai culture could be positively exploited to create and maintain a just safety culture in the RTAF aircraft maintenance divisions.

C. Human Factors Training

Human factors training is intended to reduce the likelihood of errors in the man/machine interface [27], [7] and bolster NTS. Therefore, the attendees at such courses are expected to benefit from human factors training and incorporate it into their real-life job. It is not surprising since this outcome is also reported in the survey in Section IV *F*. The officers and the NCOs who have previously taken a human factors course have a greater comprehension of the importance of such training than those who have not, and are better able to implement the knowledge and skills they have learned. Although most of the surveyed participants have attended these courses in the past, not many attend regular refresher training. It is particularly worrying to note that of the 191 participants surveyed, just over a quarter (50) admitted to never having attended *any* human factors or soft skills training. This is a concern, since human error in the aircraft maintenance process can compromise the reliability and safety of an aircraft, and could ultimately lead to loss of life, reputation, financial solvency and operational readiness [29].

Reynolds et al. [47] report that if there is no documentation mandating human factors training, then aircraft maintenance workers will not be exposed to essential safety practices. This can lead to a lack of relevant knowledge and skills. The RTAF currently has no regulations that oblige the maintenance workforce to attend regular human factors training programs. The only schemes available are organised on an *ad hoc* basis by the RTAF safety centre, and each squadron. It can be seen from this study that there are many aircraft maintenance personnel who have never attended a relevant course. Hence the RTAF needs to establish some safety regulations that require maintenance personnel to develop the competencies and skills associated with human factors and NTS, and keep them up-to-date. For example, the Australian DASA [48] specifies in DASR Part 66 that the people involved in aircraft maintenance must take the human factors course prescribed in the program curriculum for initial technical training – this is necessary if a person desires to hold a military maintenance licence. Besides, AMOs in Australia's defence sector must provide additional human factors training and maintain personal competencies through continuation training for the workforce [26].

VI. Conclusions

This study has focused on three significant gaps concerning the people who deliver continuing airworthiness in the RTAF: (i) linguistic competency, (ii) the influence of culture in the workplace, and (iii) training in human factors and NTS. The group surveyed consisted of 191 aircraft maintenance personnel drawn from the Aeronautical Engineering Divisions within two different RTAF air operators.

The results from the survey showed that the NCOs who have a direct responsibility for performing the hands-on maintenance tasks using English maintenance manuals are less confident and competent than their officers. They also think that developing English language skills is less important than honing their technical skills.

Military culture affects the perception in organisational safety, and the survey showed that NCOs are less confident in their perception of a safety climate than the officers. Furthermore, the older and more senior maintenance personnel feel that there is a better safety climate at work than the younger people, which follows from the influences of Thai national culture.

Those respondents who have previously attended human factors and NTS training appreciate its value in their day-to-day work life. Such people also comprehend the significance of such training even though there is no regulation in the RTAF to attend recurrent training.

This research also presented a variety of solutions that could help address these gaps in the delivery of continuing airworthiness. However, fundamental to all this is the need for the RTAF to adopt and implement a robust military aviation regulatory framework [49]. For example, the Australian DASA adopted the European Military Airworthiness Requirements (EMARs) from the European Defense Authority (EDA) to establish the DASR [50]. Amongst other things, these safety regulations outline various requirements and levy minimum safety standards on the management and delivery of continuing airworthiness processes [51].

Such an airworthiness management framework would greatly assist the RTAF in both specifying and preserving the skills required for a technician to hold a MAML. This would include English language competency, appreciation of human factors training, importance of soft-skills training and awareness of cultural influences, along with all the other technical skills needed for a specific job. Initial pre-requisite knowledge and competency would be fully detailed, along with the frequency and level of recurrent training. In this manner, the RTAF could improve its delivery of a safety-centric military capability.

Finally, the RTAF must recognise the considerable influence its commanding officers wield when it comes to organisational safety. The commander in a military airworthiness organisation has to ensure that sufficient resources are provided to support all the necessary training and operational requirements and to ensure that the personnel have the necessary competencies to meet the regulatory requirements [52], [53]. In addition, the commander must be a good role model, demonstrating by example an active and

constant commitment to safety and airworthiness as overriding priorities to generate a positive safety culture in the organisation [54]. By developing strong leadership at all levels and ranks within its organisation, the RTAF will be well placed to foster an improved safety culture.

APPENDIX A

TABLE VIII
THE AIRCRAFT TYPES CURRENTLY IN SERVICE WITH THE RTAF

Squadron	Aircraft Type	State of Manufacturer
102	F-16 A/B ADF	USA
103	F-16 A/B OCU	USA
201	S-92A	USA
202	Bell 412	USA
203	UH-1H	USA
	EC 725	Multi-national (EU)
401	T-50TH	South Korea / USA
402	P-180 Avanti	Italy
	DA-42MPP	Austria
403	F-16 A/B MLU	USA
404	Aerostar BP	Israel
501	AU-23A	Switzerland
601	C-130 Hercules	USA
602	B737-800	USA
	A319-115XCJ	Multi-national (EU)
	A320-200ACJ	Multi-national (EU)
	A340-541	Multi-national (EU)
603	ATR-72-500	France
	Superjet 100LR	Russia
604	CT-4A	New Zealand
	T-41D	USA
	DA-42	Austria
701	JAS 39C/D	Sweden
702	Saab 340 AEW&C	Sweden
211	F-5T Tiger	USA
231	Alpha Jet A	Germany
411	L-39ZA/ART	Czech Republic
461	Basler BT-67	USA
Primary Training Squadron	CT-4E	New Zealand
Advance Training Squadron	PC-9	Switzerland
	DA-42	Austria

APPENDIX B

TABLE IX
THE SURVEY QUESTIONS

Please take the time to complete the survey by marking each appropriate box with an X.

Rank:	Age:	Experience:	Have you ever attended a human factors or non-technical skills course?
☐ Officer	☐ 18-30 yrs	☐ Less than 5 yrs	☐ Yes
☐ NCO	☐ 31-40 yrs	☐ > 5 yrs but < 15 yrs	☐ No
	☐ More than 40 yrs	☐ More than 15 years	

ID	1. Questions - Linguistic Skills (English)	Disagree Strongly	Disagree	Neither Agree nor Disagree	Agree	Agree Strongly
1.1	You are confident using English in your job, such as following instructions in an aircraft maintenance manual written in English.	☐	☐	☐	☐	☐
1.2	You feel that English is a stumbling block in your job.	☐	☐	☐	☐	☐
1.3	Your English skills are sufficient to read the technical manual or any other documents related to maintenance.	☐	☐	☐	☐	☐
1.4	You sometimes misunderstand certain details in a maintenance manual due to the language complexity or ambiguous word meaning.	☐	☐	☐	☐	☐
1.5	You often use English to talk to your work colleagues.	☐	☐	☐	☐	☐
1.6	You are keen to develop your skills using English, such as conversation, listening to English news, reading English books, etc.	☐	☐	☐	☐	☐
1.7	English is an important language in the aviation field. Therefore, you should use the original manual in English rather than using a translated version.	☐	☐	☐	☐	☐
1.8	You believe that English proficiency is essential to understand the maintenance process fully.	☐	☐	☐	☐	☐
1.9	Your workplace should provide more training in English language skills.	☐	☐	☐	☐	☐
1.10	You think English language tuition would be a valuable part of your training.	☐	☐	☐	☐	☐

ID	2. Questions - Culture	Disagree Strongly	Disagree	Neither Agree nor Disagree	Agree	Agree Strongly
2.1	You feel free to inform or report your mistakes to other workers.	☐	☐	☐	☐	☐
2.2	If your commander or senior does something wrong, you feel confident to challenge them.	☐	☐	☐	☐	☐
2.3	When you cannot complete your task on time because you are suffering from a physical or mental condition, you feel safe informing your commander.	☐	☐	☐	☐	☐
2.4	When you cannot complete your task on time due to poor planning or lack of parts, you feel safe informing your commander.	☐	☐	☐	☐	☐
2.5	Your workplace provides enough information about safety.	☐	☐	☐	☐	☐
2.6	Your team members are honest and hard-working.	☐	☐	☐	☐	☐
2.7	Any revision required by your training (for example, preparing for a test or examination) has to be done in your own time.	☐	☐	☐	☐	☐
2.8	You always use the maintenance manual as the reference to fix the aircraft rather than your own experience.	☐	☐	☐	☐	☐
2.9	You understand the meaning and the significance of the phrase “safety culture”.	☐	☐	☐	☐	☐
2.10	Your commanders believe, model, and act out the safety culture.	☐	☐	☐	☐	☐

ID	3. Questions - Human Factors Training	Disagree Strongly	Disagree	Neither Agree nor Disagree	Agree	Agree Strongly
3.1	You understand the meaning of the term *non-technical skills*.	☐	☐	☐	☐	☐
3.2	You understand the importance of non-technical skills, such as communication or situational awareness.	☐	☐	☐	☐	☐
3.3	You are confident you can assess your own physical and mental states before you go to work.	☐	☐	☐	☐	☐
3.4	You are provided with training courses in Human Factors.	☐	☐	☐	☐	☐
3.5	Without adequate rest (at least 6 hours) your ability to do your job is compromised.	☐	☐	☐	☐	☐
3.6	You take your physical health seriously and work out, jog, or take other exercises at least three (3) days a week.	☐	☐	☐	☐	☐
3.7	Training courses that develop non-technical skills can help you improve your performance in your particular job.	☐	☐	☐	☐	☐
3.8	You would like to attend more courses that develop non-technical skills.	☐	☐	☐	☐	☐
3.9	From the communication point of view, you are aware that translating information from English to Thai can lead to a misunderstanding of the real intended meaning.	☐	☐	☐	☐	☐
3.10	You believe that working in a team is more effective than working alone.	☐	☐	☐	☐	☐

ACKNOWLEDGMENT

The authors would like to express their gratitude to the Australian Department of Defence for sponsoring the first author's airworthiness scholarship and to the RTAF for supporting this research and allowing the data to be published.

REFERENCES

[1] C. Jackson, "The organizational value framework – the two missing legs of future organizational regulatory frameworks," in *13th International Conference on Probabilistic Safety Assessment and Management (PSAM 13),* Seoul, Korea, October 2016.

[2] C. Haddon-Cave, *The Nimrod Review: An independent review into the broader issues surrounding the loss of the RAF Nimrod MR2 aircraft XV230 in Afghanistan in 2006 report.* London: The Stationery Office, 2009, ch. 20.

[3] L.E. Purton and K. Kourousis, "Military airworthiness management frameworks: a critical review", *Procedia Engineering*, vol. 80, pp. 545-564, 2014.

[4] International Civil Aviation Organisation, *Annex 8 to the convention on International Civil Aviation, airworthiness of aircraft, Part I, Definitions*, ICAO, Montréal, Nov 2016.

[5] Australian Defence Force, *Defence Aviation Safety Program: Operational airworthiness in the ADF*, ADF, Canberra, 2015.

[6] Royal Thai Air Force, *Aeronautical Engineering Manual*, RTAF, Bangkok (in Thai), 2016, unpublished.

[7] G.T. Fogarty, P.J. Murphy, W. McTernan, R. Cooper, C. Fry, K. Langford, N. Reid and H. McLean, *Aviation non-technical skills guidebook,* 2018.

[8] C.G. Drury, J. Ma, and C. Marin, "Language error in aviation maintenance," *Final Report. Marin, University of Buffalo, the State University of New York,* Sep. 2005.

[9] J. Knezevic, "Improving quality of maintenance through simplified technical English", *Journal of Quality in Maintenance Engineering*, vol. 21, no. 3, pp. 250-257, Aug. 2015.

[10] C.G. Drury, and J. Ma, "Do language barriers result in aviation maintenance errors?" in *Proceedings of the human factors and ergonomics society annual meeting*, vol. 47, no. 1, Oct. 2003, pp. 46-50, Sage CA: Los Angeles, CA: SAGE Publications.

[11] S.A. Shukri, R.M. Millar, G. Gratton, and M. Garner, "The potential risk of communication media in conveying critical information in the aircraft maintenance organisation: a case study," in *IOP Conference Series: Materials Science and Engineering*, vol. 152, no. 1, Oct. 2016, p. 012044, IOP Publishing.

[12] H.S. Jing, and A. Batteau, *The dragon in the cockpit: how western aviation concepts conflict with Chinese value systems*, Routledge, 2016, pp.15-32.

[13] S.A. Shukri, R.M. Millar, G. Gratton, and H.M. Noh, "The root cause of ability and inability to assemble and install components using written manual with or without diagrams among non-native English speakers: Root cause analysis," in *IOP Conference Series: Materials Science and Engineering*, IOP Publishing, vol. 270, no. 1, Dec. 2017, p. 012036.

[14] S. Schwartz, "A theory of cultural value orientations: explication and applications," *Comparative sociology,* vol. 5, no. 2-3, pp. 137–182, 2006.

[15] C. Kluckhohn, *Mirror for man: the relation of anthropology to modern life*. Routledge, 2017, ch.1.

[16] N. Pidgeon, and M. O'Leary, "Organizational safety culture: implications for aviation practice," *Aviation psychology in practice,* pp. 21-43, Mar. 1994.

[17] M. Rachman, *Achieving zero accidents: a study of the influences of Indonesian national and military organisational cultures on aviation safety*. A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy, School of Management, College of Business, RMIT University, Australia, 2018.

[18] B. Falconer, "Human factors and the QFI: developing tools through experience," *Multimodal Safety Management and Human Factors: Crossing the Borders of Medical, Aviation, Road and Rail Industries,* 2007.

[19] M.R. Devries, K.H. Hughes, H. Watson, and B.A. Moore, "Understanding the military culture", *Handbook of counselling military couples*, pp. 221-231, Apr. 2012.

[20] J.L. Soeters, and P.C. Boer, "Culture and flight safety in military aviation," *The International Journal of Aviation Psychology*, vol. 10, no. 2, pp.111-133, Apr. 2000.

[21] M.Y. Liao, "Safety culture in commercial aviation: differences in perspective between Chinese and Western pilots," *Safety Science,* vol. 79, pp. 193-205, Nov. 2015.

[22] R.L. Helmreich, and A.C. Merritt, *Culture at work in aviation and medicine: national, organizational and professional influences.* Aldershot: Avebury Technical, 2001, pp. 27-107.

[23] P. Hallinger and P. Kantamara, "Educational change in Thailand: Opening a window onto leadership as a cultural process," *School Leadership & Management,* vol. 20, no. 2, pp. 189-205*,* May 2000.

[24] Australian Transportation Safety Bureau, *An overview of human factors in aviation maintenance, AR-2008-055*, ATSB, Canberra, 2008.

[25] A.K. Gramopadhye, and C.G. Drury, "Human factors in aviation maintenance: how we got to where we are", *International Journal of Industrial Ergonomics,* vol. 26, no. 2, pp.125-131, 2000.

[26] Defence Aviation Safety Authority, Requirements for maintenance organisations, DASR 145, DASA, viewed 5 August 2019, <http://www.defence.gov.au/DASP/Docs/Manuals/8000-011/DASRWeb/index.htm#8791.htm>

[27] Defence Aviation Safety Authority, *Factoring the human element into maintenance*, DASA, Canberra, 2014.

[28] Y.H. Chang, and Y.C. Wang, "Significant human risk factors in aircraft maintenance technicians," *Safety Science,* vol. 48, no. 1, pp. 54-62, 2010.

[29] A. Hobbs, "An overview of human factors in aviation maintenance", *ATSB Safety Report, Aviation Research and Analysis Report AR,* vol. 55, Dec. 2008.

[30] J.C. Taylor, "The evolution and effectiveness of Maintenance Resource Management (MRM)," *International Journal of Industrial Ergonomics*, vol. 26, no. 2, pp. 201-215, Aug. 2000.

[31] A. Irwin, S. Taylor, E. Laugerud, & D. Roberts, "Investigating non-technical skills in Scottish and English aircraft maintenance teams using a mixed methodology of interviews and a questionnaire," *The International Journal of Aviation Psychology*, vol. 26, no. 3-4, pp. 105-119, Oct. 2016.

[32] N. Engel, R.E. Patey, S. Ross, and L. Wisely 2008, "Non-technical skills," *British Medical Journal*, vol. 337, Dec. 2008. (BMJ 2008; 337 doi: https://doi.org/10.1136/sbmj.0812454).

[33] G. Albaum, "The Likert scale revisited," *Market Research Society, Journal,* vol. 39, no. 2, pp. 1-21, Mar. 1997.

[34] L. Herkenhoff, and J. Fogli, *Applied statistics for business and management using Microsoft Excel*, New York: Springer, 2013, pp. 283-302.

[35] J. Sauro, "*Can you take the mean of ordinal data?*" viewed 23 September 2019, <https://measuringu.com/mean-ordinal/>

[36] M.B. Davies, *Doing a successful research project: using qualitative or quantitative methods*, Palgrave Macmillan, New York, USA, pp. 53-151, 2007.

[37] J.C. De Winter, and D. Dodou, "Five-point Likert items: t test versus Mann-Whitney-Wilcoxon," *Practical Assessment, Research & Evaluation*, vol. 15, no. 11, pp. 1-12, Oct. 2010.

[38] J.H. Flaskerud, "Cultural bias and Likert-type scales revisited," *Issues in Mental Health Nursing*, vol. 33, no. 2, pp. 130-132, Jan. 2012.

[39] L. Retief, M. Potgieter, and M. Lutz 2013, "The usefulness of the Rasch model for the refinement of Likert scale questionnaires," *African Journal of Research in Mathematics, Science and Technology Education*, vol. 17, no. 1-2, pp. 126-138, Sep. 2013.

[40] K. Rajprasit, P. Pratoomrat, and T. Wang, "Perceptions and problems of English language and communication abilities: a final check on Thai engineering undergraduates," *English Language Teaching,* vol. 8, no. 3, pp. 111-120, 2015.

[41] P. Shawcross, *English for aircraft maintenance*, Paris: Berlin, 1992.

[42] Defence Aviation Safety Authority, *Introduction to defence aviation safety,* 2nd edn, DASA, Canberra, 2019.

[43] P.H. Wilson, "Defining military culture," *The Journal of Military History*, vol. 72, no. 1, pp. 11-41, Jan. 2008.

[44] Defence Aviation Safety Authority, *Defence aviation safety management guidebook*, 21st edn, DASA, Canberra, 2016.

[45] A.V. Chatzi, 2018, "Safety management systems: an opportunity and a challenge for military aviation organisations," *Aircraft Engineering and Aerospace Technology*, vol. 91, no. 1, pp. 190-196, Jan. 2018.

[46] V.M. Iordache, and C.V. Balan, "Safety culture in modern aviation systems-civil and military," *Incas Bulletin*, vol. 8, no. 2, p. 135, Apr. 2016.

[47] R. Reynolds, E. Blickensderfer, A. Martin, K. Rossignon and V. Maleski, "Human factors training in aviation maintenance: impact on incident rates," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, Sage CA: Los Angeles, CA: SAGE Publications, vol. 54, no. 19, pp. 1518-1520, Sep. 2010.
[48] Defence Aviation Safety Authority, Military aircraft maintenance licencing, DASR 66, DASA, viewed 8 September 2019, <http://www.defence.gov.au/DASP/Docs/Manuals/8000-011/DASRWeb/index.htm#10508.htm#o16059>
[49] C.V. Thian, "Civil and military airworthiness challenges in Asia," *Aviation*, vol. 19, no. 2, pp. 78-82, Apr. 2015.
[50] Defence Aviation Safety Authority, *Military aircraft maintenance licencing,* AC 001/16 Revision 01, DASA, Canberra, 2017.
[51] H. Le, and I. Lappas, "Continuing airworthiness: major drivers and challenges in civil and military aviation," *Aviation*, vol. 19, no. 4, pp. 165-170, Oct. 2015.
[52] S. Geller, "10 leadership qualities for a total safety culture: Safety management is not enough," *Professional Safety*, vol. 45, issue 5, pp. 38-41, May 2000.
[53] F. De Florio, *Airworthiness: an introduction to aircraft certification and operations*, 3rd edn, Amsterdam, Netherlands: Butterworth-Heinemann, 2016, ch.10.
[54] M. Lundell and C. Marcham, "Leadership's effect on safety culture," *Professional Safety*, vol. 63, no. 11, pp. 36-43, Nov. 2018.