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## Risk Assessment Matrix of Operational Safety (RAMOS): Aviation Safety with a MATLAB® Design Toolkit

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## Abstract

Safety is the priority of the aviation industry that requires continuous support and improvement. While the Safety Management Systems (SMS) is mandatory for the Federal Aviation Administration (FAA) Federal Aviation Regulation (FAR) Part 121 air carriers and Part 139 airports in the United States, SMS remains optional to General Aviation (GA) due to various reasons including limited budget and manpower associated with technologies. This paper aims to promote the adoption of MATLAB<sup>®</sup> to develop a low-cost Risk Assessment Matrix of Operational Safety (RAMOS) (risk calculation and control) for GA operators. A case is presented to demonstrate the application of MATLAB<sup>®</sup> for the safety committee's usage when going through risk assessment, control options, and decision-making via a computer, tablet, or smartphone. A future comprehensive risk management toolkit can be expected with the introduction of RAMOS using MATLAB<sup>®</sup>.

*Keywords:* risk management, risk matrix, MATLAB, RAMOS

## Introduction

On July 6th, 2013, Asiana 214 operated in a Boeing 777-200ER departed from Incheon International (RKSI) to San Francisco International (KSFO). On the final approach for 28L, the pilots disengaged the auto-throttle intending to capture the glide path with lowering airspeed (National Transportation Safety Board [NTSB], 2014). Consequently, the airspeed and sink rate of the airplane became uncontrollable, which eventually caused the aircraft to strike the seawall before the runway marking (NTSB, 2014). The airplane was wrecked into pieces, resulting in the fatality of three passengers. Admittedly, many people reprimanded the pilots for their incompetency in manually flying the airplane (Ancel & Shih, 2012). However, The NTSB

(2014) report suggested that hazards were derived from the organizational management and cultural levels. Power distance and Asiana's training curriculum were also non-negligible factors (NTSB, 2014). The management system shall invariably be an intricate system that involves efforts from varied facets (Stroeve et al., 2022).

Since the inception of aviation, safety has been paramount. Aviation safety is often multifaceted and involves contributing factors from organizational and managerial sides (Adjekum, 2014; NTSB, 2014). While human error is frequently cited as the cause of any accident and human's flawed judgment can lead to catastrophic mistakes, there are also more convoluted and oblivious causes like a faulty risk assessment, training routine, airport environment, and implementation level of the safety system can also be involved (Leib & Lu, 2013). While aviation learners and professionals are acquainted with standard operating procedures (SOPs) to avert accidents or undesired events, managing potential hazards beforehand is essential.

There are typically three steps in the process of risk management (Federal Aviation Administration [FAA], 2022). First, the hazards and associated risks must be identified by all parties involved. Pilots, mechanics, and executives are responsible for ensuring safety as a top priority. For instance, pilots should complete a thorough pre-flight check before every flight to detect as many hazards as conceivable (FAA, 2022). The second step is to assess the risks and ensure flight tasks will be safely executed. The risk level can be determined once the hazards have been specified and evaluated. Safety analysis tools can ensure that the hazards are identified and examined for assessment. For this purpose, risk matrices are often employed to assess their associated risks' likelihood and severity (FAA, 2022). The third step is to mitigate the risks; a successful risk mitigation strategy will decrease the probability and/or severity determined in the assessment (FAA, 2022). Safety practitioners should substantiate that all unnecessary risks are

averted and that the risks are managed to an acceptable level. Aviation professionals have developed many safety management tools to abide by the lofty safety standards of air transportation.

The utilization of safety assessment tools has been well-researched. Most instruments identify the possible contributing factors in an active standardized process. For example, both Management Oversight and Risk Tree (MORT) and Fault Tree Analysis (FTA) are structured similarly; they utilize tree diagrams to depict the causes of an event. According to MORT implementation procedures, the tree diagram differentiates factors into distinct categories using colors (Noordwijk Risk Initiative Foundation, 2002). In comparison, FTA focuses on the upstream causes and factors leading to the event where the unwanted top failure probability level can be calculated. Both MORT and FTA can be used to sequence and define the necessary condition precedents for a presumed system failure route. MORT follows a lengthy checklist, which is time-consuming and lacks a convenient risk calculation tool.

Besides, using a risk matrix to estimate the risk level of an identified hazard is very common; the conventional approach that uses personal perception and experience could be biased. Aviation consulting firms have innovatively combined the key features of existing tools into a comprehensive safety solution. A complete but expensive safety management system (SMS) software package like ARGUS PRISM/ARMOR was developed for 14 Code of Federal Regulations (CFR) Part 5 conformance (ARGUS, n.d.) that can be tailored for different aviation sectors, such as commercial aviation service providers.

Since 2015, the FAA has issued a final rule mandating Part 121 operators and airports to implement SMS (14 CFR Part 5, 2015). SMS was initiated into the existing title 14 of CFR as a new part and has been widely used in the commercial aviation sector since (Adjekum, 2014).

Due to differences in regulatory mandates and technical requirements, some general aviation operators cannot access the same safety tools as their commercial counterparts (Adjekum & Tous, 2020). Yet the evidence indicates that implementing SMS in a general aviation training program will generate positive economic and operational outcomes (Adjekum, 2014). While the ARGUS SMS toolkit or the like has been developed mainly for major air carriers, with the deliberation of the safety analysis features aforementioned; this paper aims to create a user-friendly and low-cost risk management tool that can be incorporated into an SMS to help support risk management.

## **Literature Review**

### **Aviation Safety Management**

A successfully conformed SMS can prompt adequate operational strategies, successful recoveries, and effective operations within the safety margins (Adjekum & Tous, 2020; ). Such an SMS will foster positive safety culture, adapt everyone's input equally, and provide a sense of involvement to encourage more insights and contributions from members of each organization (Bos & Lu, 2007; Wood, 2003). The nature of the industry propels the endeavor of putting considerable emphasis on precluding human errors and near misses (Perezgonzalez, 2009). The measurement of the state of safety should be the organization's "leading indicators" like SMS, safety climate, or culture, not "lagging indicators" like accidents or incidents (Adjekum, 2014;; Lu et al, 2005; Ni et al., 2019; Yule, 2003). Both International Civil Aviation Organization (ICAO) and the FAA have advocated that the safety management system (SMS) should be operated as a cardinal and prognostic apparatus to augment the resiliency of the safety system and safety culture (FAA, 2015; ICAO, 2018; Lu, Young & Schreckengast, 2011).

## Safety Culture & Technological Aids

*Safety Culture.* Aviation safety management systems have been well investigated in diverse operating environments, notably in global commercial aviation. Australian Transportation Safety Bureau (ATSB) (2004) reported on the commercial pilots' perception of their safety climate based on feedback from surveys. The responses were gleaned from regular public transports (RPTs), chartered, aerial, and business pilots (ATSB, 2004). The survey results indicated that there is no significant difference in safety climate perceptions among these commercial pilots. The report stated that the uniform professional safety climate formed a unique culture across commercial operating pilots (ATSB, 2004). Similarly, Gibbons et al. (2006) created a survey using confirmatory factor analysis (CFA) to evaluate the perceptions of SMS amongst American commercial operators. The survey contained five distinct themes to assess the safety cultures amongst Part 121 and Part 135 operators (Gibbons et al., 2006). While the initial proposed model had psychometric imperfections, the paper's analysis still offered deep insights into commercial aviation safety culture. When analyzing safety culture in a specific operational context, Leib and Lu (2013) also highlighted the significance of comprising a variety of aviation safety stakeholders in safety management to buttress the efficacy of an SMS.

While the effectiveness and FAA regulations have popularized SMS amongst Part 121 operators; there has also been a gap identified between safety culture and organizational management factors, specifically in the collegiate aviation programs, which is an essential sector of General Aviation (Adjekum, 2014; Adjekum and Tous, 2020; Reason, 2008). Undoubtedly, collegiate aviation programs could benefit from utilizing some of the safety assessment tools that have already been proven successful for commercial aviation operators. In addition, the accident of N452DA Learjet in 2017, operated by Trans-Pacific Air Charter under 14 Code of Federal

Regulations § 91 (Part 91), revealed human factors and incompetent management as causal factors that called the SMS implementation to improve the safety culture (Ott et al., 2022).

While a successful hazard reporting system and risk assessment would lead to a successful SMS (Lu, Schreckengast & Jia, 2011), Adjekum and Tous (2020) pointed out that organizational factors such as *Principles, Policy, Procedures, and Practices* (4Ps) can be used to assess the safety culture and SMSs at collegiate aviation programs. Although all 4Ps strongly influence the outcome of a resilient safety culture, Adjekum and Tous (2020) specified that safety policies had the strongest influence on the hazard reporting system, which indicated that safety policies should embrace a non-punitive clause as well as just culture.

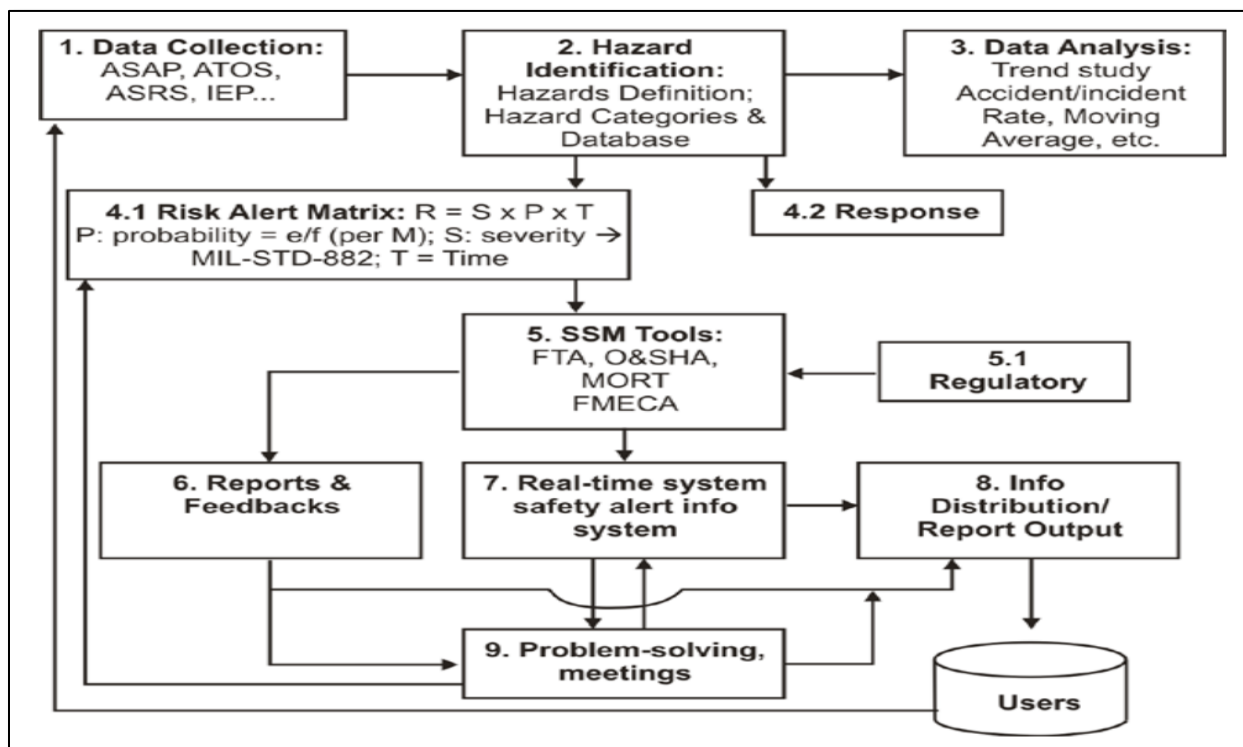
**Technological Aids.** The conventional pedagogical strategy in aviation safety theory focuses on a reactive approach to accident or incident causal analysis. A reactive method will serve well in some regions of operational safety, yet it lacks the proactive element to discover and measure insidious precedent hazards of a task (Adjekum and Tous, 2020; Patriarca et al., 2019; Reason, 2008). As a result, many technological application developers focus on fortifying proactive safety tools in diverse operational environments, such as Fishbone Ishikawa Analysis (Ott et al., 2022). Dai et al. (2021) propounded a logistic regression model to predict go-around occurrences based on air traffic and weather conditions. The paper suggested a “prediction-based” application of monitoring and altering the related contributing factors to help controllers and pilots in decision-making. Patriarca et al. (2019) also analyzed an incremental proactive risk assessment strategy building upon a Toolkit for Air Traffic Management (ATM) Occurrence Investigation (TOKAI). TOKAI is a reporting tool for Air Navigation Service Providers (ANSPs) to centralize safety-related factors into a holistic safety performance to improve

decision-making. The data-driven analyses are structured to consolidate the holistic safety of the ATM system and have been modified and adopted by many European governments.

Similar to Lu-Bos-Caldwell Aviation System Safety Management Model (ASSMM), presenting a comprehensive safety management model for the aviation industry (see Figure 1) (Lu, Bos & Caldwell, 2007, p.36), Patriarca et al. (2019) proposed a method with a three-step approach: 1) to generate a two-dimensional reporting method for the dataset, 2) to combine datasets into a final co-reporting matrix, and 3) to create a Pearson co-reporting matrix.

**Figure 1**

*Aviation System Safety Management Model (ASSMM)*



The TOKAI method that Patriarca et al. (2019) constructed provided a “user-friendly” interactive medium for air traffic managers to monitor and assess a system’s safety level through



a systemic lens. The paper also advocated for the usability of the technological tool in prioritizing reported factors based on the frequency of reports. Although the toolkit initially presented a solution for air traffic management, it does hold versatility for other aviation sectors. Without a doubt, safety practitioners across other aviation professions can benefit from adopting an intuitive and accessible risk matrix programmed tool.

In conjunction, the research concerns of this study have been identified to be:

1. The scarcity of low-cost and accessible electronic risk matrix analysis tools; and
2. The lack of a common programming application in the General Aviation field.

### **Research Objective**

The purpose of implementing SMS is to ensure operational safety by identifying potentials, calculating potential risks, and providing safety controls while embracing the just culture to enable organizational safety and sustainability. The research concentrates on demonstrating a tool that pilots or other safety practitioners can operate to preside over risks more conveniently. The study aims to showcase a low-cost, configurable, and open-access programmable approach to fill one of the technical gaps and enhance General Aviation safety.

### **Methodology**

#### **Research Instrument**

The Risk Assessment Matrix of Operational Safety (RAMOS) tool was developed under the MATLAB® framework. MATLAB® is a powerful device with pre-programmed algorithms that engineers and mathematicians typically use to simulate specific environments for modeling, testing, and computing. Manno et al. (2014) devised a software tool called RAATSS using MATLAB®. RAATSS enabled researchers to dissect the dynamic fault tree differently. With a list of set rules, the dynamic gates of the fault tree can be processed through the novel adaptive

transition system (ATS). Ni et al. (2019) implemented a Principal Component Analysis (PCA) to forecast incident rates in Chinese civil aviation using MATLAB<sup>®</sup>. The analysis tool was based on a deep belief network to process the main factors from 68 unsafe events to predict future accidents or incidents. Both applications demonstrated MATLAB<sup>®</sup>'s versatility in forming adaptive frameworks for safety analysis.

Additionally, to determine the suitable programming language for this study, the construction of RAMOS required:

1. Graphical interface that can be employed for a risk matrix
2. Package of codable Graphical User Interface (GUI)
3. The capability of control and task modules from the live editor module
4. The ability to provide step-by-step guidance for users when using RAMOS

MATLAB<sup>®</sup> fulfilled all the requirements above. Furthermore, MATLAB<sup>®</sup> enables researchers to construct multi-dimensional matrices that can be comprised into a user-friendly and configurable product. To conclude, MATLAB<sup>®</sup> was the optimal option due to its alignment with the study's objective. The intent of materializing RAMOS was to deliver a novel, user-friendly mechanism to facilitate risk management.

### **Design and Implementation of RAMOS**

To conceive a desirable safety tool, the emphasis of the literature review was explicitly associated with safety management, risk assessment system analysis, just culture, and technological applications in hazard evaluation; a gap was identified that a risk matrix assessment tool like RAMOS could be a viable product for the current aviation risk analysis process. Before initiating the development process of RAMOS, it was critical to locate the operational user environment of such a tool. As mentioned in the literature review, adaptability

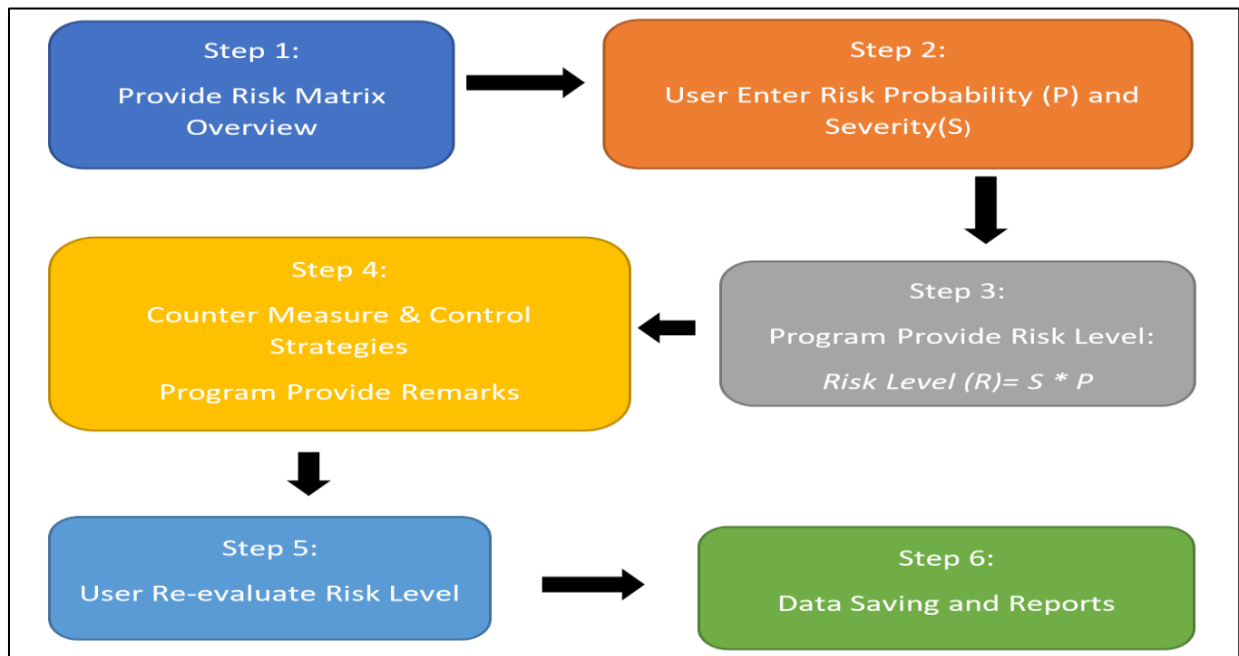
to diverse operating environments would be an essential attribute. Hence, RAMOS should be equipped with the following functions:

- User input of risk assessment criteria, including severity and probability
- Representation of the risk assessment should be confined to quantitative values and color-coded themes
- Support for configuration into to the needs of another aviation profession
- Countermeasures at the end of the risk assessment process
- Hazard re-evaluation to demonstrate the risk mitigation process for comparison
- Results into batch reports, so they can be collected into the uplink database

As shown below in Figure 2, there are six developmental steps of RAMOS:

**Figure 2**

*RAMOS Developmental Process*



The first step of the developmental process was to provide the risk matrix overview to the users of RAMOS. An outline of the hazard processing principles of RAMOS was presented to users to learn about the associated risks, likelihood, and severity criteria.

In the second step, RAMOS would permit users to define the probability and severity of the event. The probability, as in the likelihood of the event's occurrence, was categorized into "very unlikely (1)", "unlikely (2)", "possible (3)", "likely (4)", and "very likely (5)" on the y-axis. The severity, as in the consequences of the event, was categorized into "negligible (1)", "minor (2)", "moderate (3)", "significant (4)", and "severe (5)" on the x-axis (See Table 1).

**Table 1**

*Exemplary Hazard Probability x Severity Levels*

Score	Probability	Severity
1	Very Unlikely	Negligible
2	Unlikely	Minor
3	Possible	Moderate
4	Likely	Significant
5	Very Likely	Severe

*Note.* This table shows the relative scores for probability and severity;

both are ranked in ascending order from one to five.

The third step of RAMOS contained the process of risk-level computation. As the equation below indicates, the risk level score would be the product of the entered probability and severity levels (Cusick et al., 2017, p. 340).

While risk (R) is the product of probability (P) and severity (S), the corresponding scores of two axes are exhibited in Table 2, the authors demonstrated the computed risk level scores depicted in six colors including Red (20~25, extreme risk, STOP operation); Salmon (15~19,

very high risk, immediate actions); Orange (10~14, high risk, urgent actions); Yellow (4~9, medium risk, discussion before actions); Light Green (2~3, low risk, acceptable and monitoring); and Green (1~2, very low risk, desirable and monitoring).

**Table 2**

*Exemplary Risk Matrix (Score = Hazard Probability x Severity Levels) with Color Codes*

Color	Risk Level	Score
Green	Very Low	1-2
Light Green	Low	3-4
Yellow	Medium	5~9
Orange	High	10-12
Salmon	Very High	13-16
Red	Extremely High	17-25

*Note.* This table lists the six distinct colors used to represent risk levels. The scores are computed with the equation Risk =Severity x Probability.

The fourth step of RAMOS focused on offering the proper countermeasure actions to assist users in abating the risks to an appropriate level. RAMOS then provided elimination methods and control strategies in yielding mitigation plans. There were five major elimination methods, *Elimination of Hazard*, *Reduction of Hazard Level*, *Employment of Safety Devices*, *Warning and Alert Methods*, and *Safety Procedures*. Also, *Design and Engineering*, *Safety Devices*, *Warning Devices*, *Procedure and Training*, and *Personal Protective Equipment* were the five control strategies of RAMOS. After one of the recommended mitigation plans had been accepted, RAMOS proceeded to proffer facts and remarks concerning the hazard assessment process.

RAMOS then authorized users to re-evaluate the risk levels, which was the fifth step. The re-evaluation process would be analogous to the second step of RAMOS when the hazards were

analyzed for the first time. This step was essential mainly because users could envision how the hazards were processed. Implementing countermeasures also significantly reduces the risk levels.

RAMOS's final step was to generate a report from the yielded risk assessment analysis. The analysis would contain the assessment, countermeasures, elimination methods, and control strategies to deliver ample information to users.

## **Results**

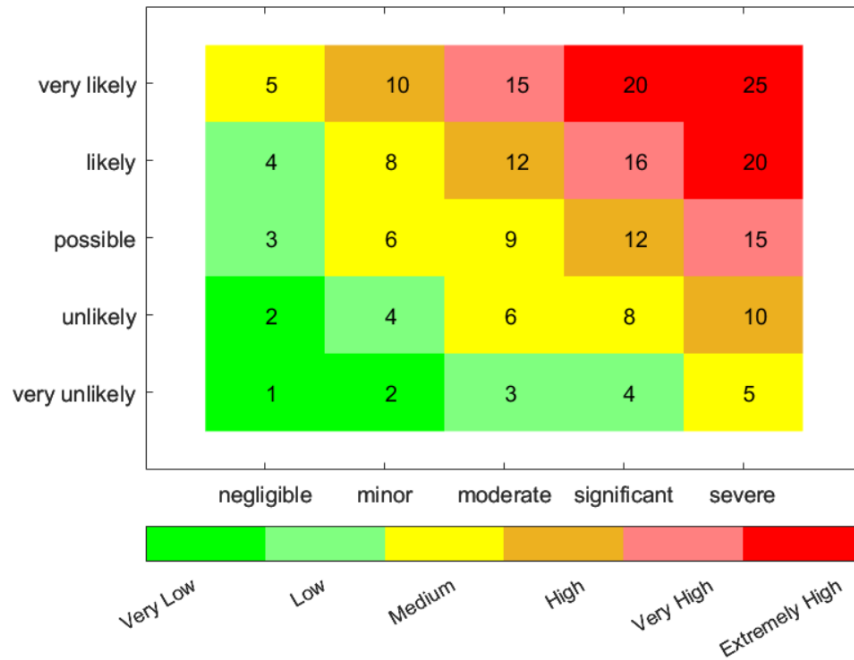
### **Key Features of RAMOS**

The exemplary risk matrix contains both the x and y axis of severity and probability, shown in Figure 3. The prototype model utilized a five-by-five matrix and six colors representing different risk levels. The legend on the bottom of the figure illustrates the risk levels' color spectrum. The original MATLAB<sup>®</sup> codes are provided in Appendix for public Open-Source sharing.

For showcasing the process of RAMOS, the initial risk matrix (see Figure 3) is provided to exemplify the computation and presentation of a hazard's risk level consisting of both likelihood and severity, as well as the colors of all risk levels.

**Figure 3**

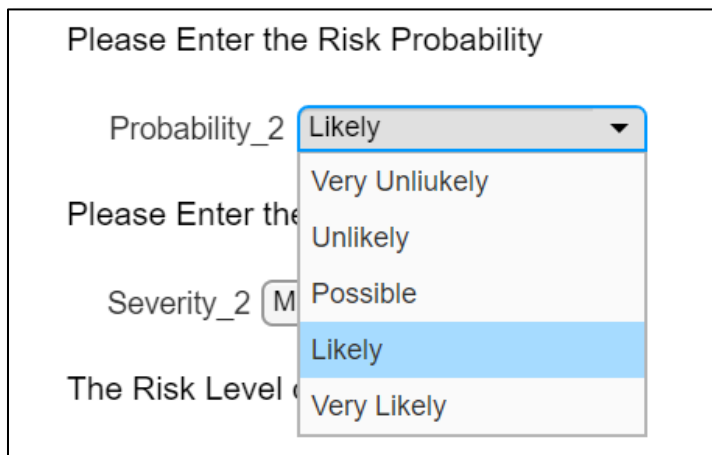
*Example of Risk Matrix in RAMOS*



After a hazard is reported or observed, RAMOS users could enter the probability (see Figure 4) and severity (see Figure 5) as their initial input of the undesired event.

**Figure 4**

*Probability (P) Drop-Down Options*



**Figure 5***Severity (S) Drop-Down Options*

Please Enter the Risk Severity

Severity\_2 Minor ▼

The Risk Lev

The Risk 1

Additional par

Counter-Measure Part

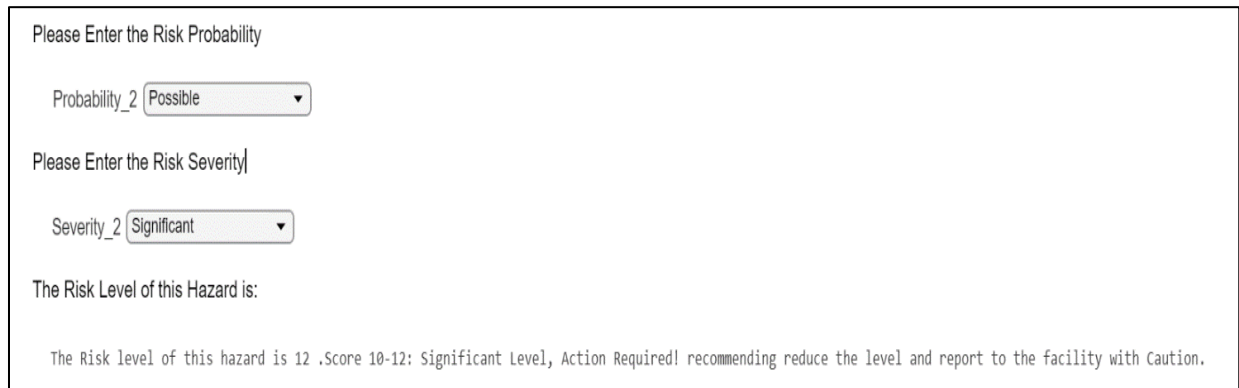
Figures 4 and 5 indicate the risk probability and severity selections and their drop-down menus. RAMOS then processes the user input scores by multiplying them to obtain the product of an initial risk level.

As shown in Figure 6, fundamental risk level analysis would be delivered once RAMOS conveyed the score from an individual committee member's input. RAMOS would display the risk level and interval of the calculated score. Per the safety committee's collective discussion, if the initially computed risk is higher than the "medium risk" level (in this demonstration, the risk is 12, goldenrod color), the program would alert users to take actions to lower the risk. This criterion is decided by the entire review committee based on archived data, experience, policy, and collective bargaining process. Again, the risk index of "12" is not acceptable according to the company's standards and needs action to be tacked to lessen the initial risk.



## Figure 6

### *Risk Level Assessment with Determined Probability and Severity*



Please Enter the Risk Probability

Probability\_2 Possible ▾

Please Enter the Risk Severity|

Severity\_2 Significant ▾

The Risk Level of this Hazard is:

The Risk level of this hazard is 12 .Score 10-12: Significant Level, Action Required! recommending reduce the level and report to the facility with Caution.

During the committee's review, the program delivered two parts of solutions. The first part (Part 1) contains categories of *countermeasures*, including elimination, reduction, safety devices, warning or alert, and safety procedure/training (see Figure 7). Once the committee has selected a countermeasure, RAMOS will furnish the committee with more details shown in the remark. Figure 8 illustrates two specified countermeasures: 3 (safety devices) and 5 (safety procedures). The safety committee can see suggested risk control options such as mechanical equipment, administrative, education/training, or manual revisions (see Figure 8).

**Figure 7***Suggested Countermeasures with Associated Risk Levels*

<input checked="" type="checkbox"/> Counter_Measure_3 Employment_of_Safety_Devices = <i>Logical</i> 1 Remark: Employment of Safety Devices is selected. Additional Safety Devices is required. This control method is not fail-safe, but its mechanical nature often prevents exposure to potential hazards
<input type="checkbox"/> Counter_Measure_4 Warning_and_Alert_Methods = <i>Logical</i> 0
<input checked="" type="checkbox"/> Counter_Measure_5 Safety_Procedures = <i>Logical</i> 1 Remark: Safety Procedures is selected. Administrative control strategies. Considered "soft" control measure. Training and regulaiton can be put into place, but human error can negate this type of control.

**Figure 8***Countermeasures - Examples with remarks*

Counter-Measure Part  To reduce that risk level, Please select the proper solutions to reduce the risk. Five_Counter_Measure_part = 'There are Five main counter-measure solutions, please select all possible options.' <input type="checkbox"/> Counter_Measure_1 Elimination_of_Hazard = <i>Logical</i> 0 <input type="checkbox"/> Counter_Measure_2 Reduction_of_Hazard_Level = <i>Logical</i> 0 <input type="checkbox"/> Counter_Measure_3 Employment_of_Safety_Devices = <i>Logical</i> 0 <input type="checkbox"/> Counter_Measure_4 Warning_and_Alert_Methods = <i>Logical</i> 0 <input type="checkbox"/> Counter_Measure_5 Safety_Procedures = <i>Logical</i> 0
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Part 2 of the solution is the *risk control* strategies, including design and engineering, safety devices, warning devices, procedures and training, and personal protective equipment (see Figure 9). Like the suggested countermeasures in Part 1, once the committee determines the risk control strategy, RAMOS will also provide important remarks associated with the specific selection. In Figure 10, the committees specify control strategies 4 (procedures and training) and 5 (personal protective equipment); RAMOS provides a remark of “Mainly intend to reduce the probability and subsequently the severity” and “Reduce severity from materialized hazard” for control strategies 4 and 5 accordingly to verify committee’s selected control strategies (see Figure 10).

## Figure 9

### *Suggested Control Strategies with Associated Risk Levels*

Select the proper control strategies, techniques, and equipment:

Strategy\_01

Design\_and\_Engineering = *Logical*  
0

Strategies\_02

Safety\_Devices = *Logical*  
0

Strategies\_03

Warning\_Devices = *Logical*  
0

Strategies\_04

Procedures\_and\_Training = *Logical*  
0

Strategies\_05

Personal\_Protective\_Equipment = *Logical*  
0

**Figure 10***Control Strategies – Examples with Remarks*

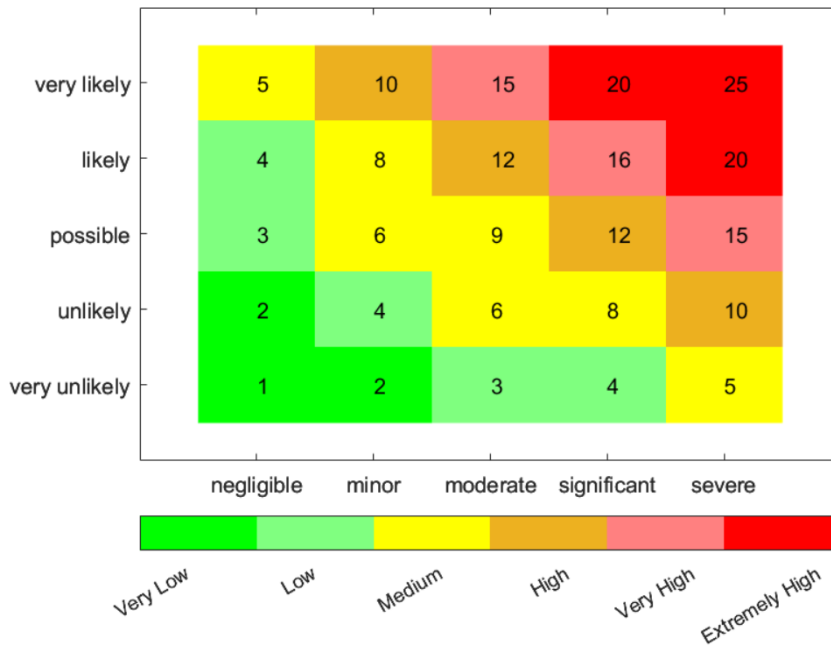
<input checked="" type="checkbox"/> Strategies_04  Procedures_and_Training = <i>logical</i> 1  Remark: Procedures and Training is selected. Mainly intend to reduce the probability, subsequently reduce severity.
<input checked="" type="checkbox"/> Strategies_05  Personal_Protective_Equipment = <i>logical</i> 1  Remark: Personal Protective Equipment is selected. Reduce the severity from a materialized hazard. Considered last line of defense as it requires human input to be worn correctly.

It should be noted that RAMOS follows logical processing for the committee to determine the optimized or desired solution. After the users have specified appropriate choices to decrease the risk level, RAMOS requests to re-run the risk assessment by the committee. The revised risk level score should be lower than the initial one, as seen in Figure 11. In this example, the committee's congruently recalculated score is 1, which is a desirable level. A "Remark" section also enables the committee to record the decision-making process and the rationality behind the selected countermeasure category and risk control strategies. After the risk re-assessment has been conducted, RAMOS then saves the computed result and any relevant

remarks into a separate file for recordkeeping. *Recordkeeping* is an important feature that helps shape a hazard database for future continuous safety monitoring, assurance, and promotion.

**Figure 11**

*Risk Matrix After Implementing Mitigation Strategies*



Please Enter the Risk Probability

Probability\_2

Please Enter the Risk Severity

Severity\_2

The Risk Level of this Hazard is:

The Risk level of this hazard is 1 .Score 1-2: Negligible Risk Level.

**Product Advocate**

RAMOS was conceived to assist safety analysis in diverse operational settings. As aeronautical engineering has advanced aircraft design in the past decades, the chances of

mechanical failures have been significantly lowered (Gray et al., 2018). While human errors due to organizational oversights are emerging, aviation safety practitioners can conveniently perform RAMOS to identify potential risks carefully and promptly. The advocate of RAMOS aims to deliver a hands-on tool that can be integrated into a comprehensive SMS in the organization. Safety risk management (SRM) focuses on pinpointing hazards in the organization's system. While Title 14 *CFR* Part 5 (2015) defines SMS as a systemic approach to effectively manage and control risks (14 *CFR* Part 5, 2015), the introduction of RAMOS contributes as a tool to support safety responsibility, accountability, and integrity.

### **Discussion**

While most FAR 121 air carriers and Part 139 commercial airports do possess sufficient budget to customize and implement SMS, the GA industry faces a financial shortage when considering implementation of SMS. The authors demonstrated the application of MATLAB® to deliver a user-friendly and low-cost risk assessment tool, RAMOS, for budget-constrained general aviation operators. In particular, the FAA has recently published a new Notice of Proposed Rulemaking (NPRM) to expand the 14 *CFR* Part 5 Safety Management Systems beyond FAR Part 121 operators to include Part 135 air taxi and Part 91.147 air tour operators (FAA, 2023 January 10, p.7). The AL-60 NPRM does show the government's urgent call for safety management, which simultaneously sheds light on the vital benefit of the RAMOS or the like. While near-term mandatory compliance could be imminent, the authors showcased the merit of ROMAS that helps form a concrete pillar of SMS, the Safety Risk Management (SRM).

RAMOS was designed to be utilized in different operational environments, including flight, maintenance, ground, traffic management, and more. Without a doubt, the commitment to safety investment from a top leadership chain would support the resilience of operational safety

(Adjekum & Tous, 2020). While the authors demonstrated the free risk assessment tool, the recommended process should include a committee only if a hazard is complicated and needs further brainstorming. Otherwise, an individual assessment and decision would suffice. Identifying the significance of an observed hazard needs training on hazard categories and specified standards.

### **Conclusion**

The main objective of this study is to showcase the concept of a low-cost programmable risk matrix tool for collective safety risk assessment, control options, and archived hazard reports to fulfilling safety assurance and safety promotion. While there are software packages available in the market, the cost could be a significant financial burden to low-cost air service providers. RAMOS seeks to supply an open-access and configurable practical tool for aviation safety professionals. Setting up a data archive system would tremendously benefit data storing and searching. Using open-source language like MATLAB<sup>®</sup>, the proposed instrument can be conformed to be a cost-benefit and convenient alternative compared to the commercial products in the market. RAMOS can benefit aviation professionals in assessing hazardous situations at the front line and as a tabletop classroom exercise for students. Based on the proposed handy toolkit, flight, engineering, cabin, or ramp/ground crews can use a modified version of RAMOS to identify unique hazards, calculate risk levels, and collectively suggest a countermeasure for the reported abnormal issue. For instance, when a student pilot encounters a low visibility weather condition during pre-flight, RAMOS can function as a user-friendly risk assessment program through smartphones or electronic tablets to calculate potential risk without a paperback manual. The toolkit could simultaneously allow safety managers to build a database by recording the reported hazards and their respective decision-making processes of each user of RAMOS. In

return, it patronizes the pillars of SMS: proactive safety risk management, risk assurance, and promotion.

A similar programming technique can be used to develop a holistic safety management system. It is because RAMOS can be converted into an APP or online HTML for free applications where the open source (see Appendix) can be adapted to customize a safety management program as users or developers see fit.

### **Future Study**

Building on the construction of RAMOS, practitioners can propose a follow-up study to test the toolkit for improvement as well as develop a comprehensive risk management product. Also, a real-time hazard display dashboard for prompt safety information sharing, alerts, and responses is preferred by embracing the *Smart Safety* concept. Other alternatives to MATLAB<sup>®</sup> could help develop a low-cost tool for aviation risk management, and readers are encouraged to apply.



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## Appendix: MATLAB® Code

```

C = [3 4 5 6 6; 2 3 4 5 6; 2 3 3 4 5; 1 2 3 3 4; 1 1 2 2 3];
V = [1 2 3 4 5; 2 4 6 8 10; 3 6 9 12 15; 4 8 12 16 20; 5 10 15 20 25];
ax=axes
hold on
[X,Y] = meshgrid(1:size(C,1),1:size(C,2))
h = imagesc(X(:,Y(:),flipud(C))
cmap = [0 1 0; 0.5 1 0.5; 1 1 0; 0.929 0.694 0.125; 1 0.5 0.5; 1 0 0];
%see notes from the cmap/colormap from 3 by 3 matrix option.
str = sprintf('%d',V(:))
text(X(:,Y(:),str)
RowLabels = {'very unlikely','unlikely','possible','likely','very likely'};
ColLabels = {'negligible','minor','moderate','significant','severe'};
set(gca,'xtick',unique(X),...
    'ytick',unique(Y),...
    'yticklabels',RowLabels,...
    'xticklabels',ColLabels)
cb = colorbar(ax,'location','southoutside')
set(cb,'ticks',[1.3 2.2 3.1 4 4.9 5.8],...
    'ticklabels',{'Very Low','Low','Medium','High','Very High','Extremely High'},...
    'ticklength',0)
box on
set(ax,'layer','top')
colormap(cmap)

hold on
% else
% disp(['you have entered the wrong input, please input 3 for 3 by 3 matrix' ...
%     ' and 5 for 5 by 5 matrix']);
% need to make this IF/ELSEIF statement a closed loop, so that if the
% user noticed that they have the wrong input they can goback and fix
% it.

Please Enter the Risk Probability
Probability_2 = 4;

Please Enter the Risk Severity
Severity_2 = 5;

The Risk Level of this Hazard is:
Risk_level_5_by_5 = Probability_2 * Severity_2;
if Risk_level_5_by_5 < 3;
    Result_3 = ['The Risk level of this hazard is ', num2str(Risk_level_5_by_5), '!',...
    'Score 1-2: Negligible Risk Level.'];
    disp(Result_3);
elseif (2 < Risk_level_5_by_5)&& (Risk_level_5_by_5 < 5);
    Result_3 = ['The Risk level of this hazard is ', num2str(Risk_level_5_by_5), '!',...
    'Score 3-4: Minor Level, recommending reduce the level and report to the facility.'];
    disp(Result_3);

```

```

elseif (4 < Risk_level_5_by_5)&& (Risk_level_5_by_5 <10);
    Result_3 = ["The Risk level of this hazard is ", num2str(Risk_level_5_by_5), ' ',...
        'Score 5-9: Medium Level, recommending reduce the level and report to the facility with Caution.'];
    disp(Result_3);
elseif (9 < Risk_level_5_by_5)&& (Risk_level_5_by_5 <15);
    Result_3 = ["The Risk level of this hazard is ", num2str(Risk_level_5_by_5), ' ',...
        'Score 10-12: Significant Level, Action Required! recommending reduce the level and report to the
facility with Caution.'];
    disp(Result_3);
elseif (14 < Risk_level_5_by_5)&& (Risk_level_5_by_5 <17);
    Result_3 = ["The Risk level of this hazard is ", num2str(Risk_level_5_by_5), ' ',...
        'Score 15-16: Very High Level, Action Required! recommending reduce the level and report to the facility
with Caution.'];
    disp(Result_3);
else
    Result_3 = ["The Risk level of this hazard is ", num2str(Risk_level_5_by_5), ' ',...
        'Score 20-25: Extreme Level! Do Not Fly! Immediate Action Required! Report to the facility and seek
actions.'];
    disp(Result_3);
end
% This is the Original 3 BY 3 Matrix IF/ELSEIF code, do not erase!!!!
% if Risk_level_3_by_3 < 3;
%     Result_3 = ["The Risk level of this hazard is ", num2str(Risk_level_3_by_3), ' ',...
%     'Score 1-2: Negligible Risk Level.'];
%     disp(Result_3);
% elseif (2 < Risk_level_3_by_3)&& (Risk_level_3_by_3 <6);
%     Result_3 = ["The Risk level of this hazard is ", num2str(Risk_level_3_by_3), ' ',...
%     'Score 3-4: Medium Level, recommending reduce the level and report to the facility.'];
%     disp(Result_3);
% else
%     Result_3 = ["The Risk level of this hazard is ", num2str(Risk_level_3_by_3), ' ',...
%     'Score 6-9: Immediate Action Required: Report to the facility and seek actions.'];
%     disp(Result_3);
% end
% Result_3 = ["The Risk level of this hazard is ", num2str(Risk_level_5_by_5), ' .'];
% disp(Result_3);

```

Additional part to the program.

```
%control options. dropdown list of options to reduce the color.
```

```
%save output.
```

```
%record data in the future.
```

```
%recommendation
```

```
%give counter measure options. back to 573 there are DEFWP. warning sign,  
%device, design, practice, training, etc. Make this a drop down list.  
%  
%corrected risk assessment. do risk assessment again.  
  
%generate a report make it become a data.  
Counter-Measure Part  
Counter_Measure_Title = 'To reduce the risk level, Please select the proper solutions to reduce the risk.';  
disp(Counter_Measure_Title);  
Five_Counter_Measure_part = 'There are Five main counter-measure solutions, please select all possible  
options.'  
%notice that in this case, the cost of counter-measure is not included.  
%In this prototype, we recommend users to select counter-measure wisely.  
  
%Design for minimum hazard;  
%Provide safety devices;  
%Provide warning devices;  
%Control with procedures and training; and  
%Accept remaining residual hazards.  
  
Elimination_of_Hazard = false  
while Elimination_of_Hazard == true  
    disp('Remark:')  
    disp('Elimination of Hazard is selected.')  
    disp('Engineering Control Strategy eliminate the safety risk completely.');  
    disp('This step require contact manufacture for specific part redesign.');  
    disp(' ');  
    break  
end  
  
Reduction_of_Hazard_Level = false  
while Reduction_of_Hazard_Level == true  
    disp('Remark:')  
    disp('Reduction Hazard Level is selected.')  
    disp('Reduction of severity or likelihood of the event.')  
    disp('Reduces its overall impact, moving its classification from unacceptable to acceptable on the  
matrix');  
    disp(' ');  
    break  
end  
  
Employment_of_Safety_Devices = true  
while Employment_of_Safety_Devices == true
```

```

disp('Remark:')
disp('Employment of Safety Devices is selected.')
disp('Additional Safety Devices is required.');
```

disp("This control method is not fail-safe, but its mechanical nature often prevents exposure to potential hazards");

```

disp(' ');
break
end

Warning_and_Alert_Methods = false

while Warning_and_Alert_Methods == true
disp('Remark:')
disp('Warning and Alert Methods is selected.')
disp('Provide visual or audible warning sign or horn.');
```

disp('One weakness is that after warning sign is received, human action is necessary.');

```

break
end

Safety_Procedures = true
while Safety_Procedures == true
disp('Remark:')
disp('Safety Procedures is selected.')
disp('Administrative control strategies.');
```

disp('Considered "soft" control measure.');

disp("Training and regulation can be put into place, but human error can negate this type of control.");

```

break
end
%First solution option listed above.
%Second solution option listed below.

disp('Select the proper control strategies, techniques, and equipment:')
Design_and_Engineering = false
while Design_and_Engineering == true
disp('Remark:')
disp('Design and Engineering is selected.')
disp('Work on the probability side of the risk equation.')
```

disp('Subsequently reduces/eliminates severity.');

```

disp(' ');
break
end

Safety_Devices = false

```



```

while Safety_Devices == true
    disp('Remark:')
    disp('Safety Devices is selected.')
    disp('Device can be either active or passive.')
    disp('Similar to Design and Engineering, but less effective.')
    disp('Active safety devices require human action. not as effective as passive devices.')
    disp('Passive requires sense and deploy automatically.')
    disp('  ')
    break
end

```

```

Warning_Devices = false
while Warning_Devices == true
    disp('Remark:')
    disp('Warning Devices is selected.')
    disp('Increase the change of one being aware of the potential hazard.')
    disp('  ')
    break
end

```

```

Procedures_and_Training = true
while Procedures_and_Training == true
    disp('Remark:')
    disp('Procedures and Training is selected.')
    disp('Mainly intend to reduce the probability, subsequently reduce severity.')
    disp('  ')
    break
end

```

```

Personal_Protective_Equipment = true
while Personal_Protective_Equipment == true
    disp('Remark:')
    disp('Personal Protective Equipment is selected.')
    disp('Reduce the severity from a materialized hazard.')
    disp('Considered last line of defense as it requires human input to be worn correctly. ')
    disp('  ')
    break
end

```

Now after employees discussed and selected the proper ways to reduce the hazard, it is required to run risk matrix again.

```

C = [3 4 5 6 6; 2 3 4 5 6; 2 3 3 4 5; 1 2 3 3 4; 1 1 2 2 3];
V = [1 2 3 4 5; 2 4 6 8 10; 3 6 9 12 15; 4 8 12 16 20; 5 10 15 20 25];
ax=axes
hold on

```

```

[X,Y] = meshgrid(1:size(C,1),1:size(C,2))
h = imagesc(X(:,Y(:),flipud(C))
cmap = [0 1 0;0.5 1 0.5;1 1 0;0.929 0.694 0.125;1 0.5 0.5;1 0 0];
%see notes from the cmap/colormap from 3 by 3 matrix option.
str = sprintf('%d',V(:))
text(X(:,Y(:),str)
RowLabels = {'very unlikely','unlikely','possible','likely','very likely'};
ColLabels = {'negligible','minor','moderate','significant','severe'};
set(gca,'xtick',unique(X),...
'ytick',unique(Y),...
'yticklabels',RowLabels,...
'xticklabels',ColLabels)
cb = colorbar(ax,'location','southoutside')
set(cb,'ticks',[1.3 2.2 3.1 4 4.9 5.8],...
'ticklabels',{'Very Low','Low','Medium','High','Very High','Extremely High'},...
'ticklength',0)
box on
set(ax,'layer','top')
colormap(cmap)

```

Please Enter the Risk Probability

Probability\_2 = 1;

Please Enter the Risk Severity

Severity\_2 = 1;

The Risk Level of this Hazard is:

Risk\_level\_5\_by\_5 = Probability\_2 \* Severity\_2;

if Risk\_level\_5\_by\_5 < 3;

Result\_3 = ['The Risk level of this hazard is ', num2str(Risk\_level\_5\_by\_5), ' ',...  
'Score 1-2: Negligible Risk Level.'];

disp(Result\_3);

elseif (2 < Risk\_level\_5\_by\_5)&& (Risk\_level\_5\_by\_5 < 5);

Result\_3 = ['The Risk level of this hazard is ', num2str(Risk\_level\_5\_by\_5), ' ',...  
'Score 3-4: Minor Level, recommending reduce the level and report to the facility.'];

disp(Result\_3);

elseif (4 < Risk\_level\_5\_by\_5)&& (Risk\_level\_5\_by\_5 < 10);

Result\_3 = ['The Risk level of this hazard is ', num2str(Risk\_level\_5\_by\_5), ' ',...  
'Score 5-9: Medium Level, recommending reduce the level and report to the facility with Caution.'];

disp(Result\_3);

elseif (9 < Risk\_level\_5\_by\_5)&& (Risk\_level\_5\_by\_5 < 15);

Result\_3 = ['The Risk level of this hazard is ', num2str(Risk\_level\_5\_by\_5), ' ',...  
'Score 10-12: Significant Level, Action Required! recommending reduce the level and report to the facility with Caution.'];

disp(Result\_3);

elseif (14 < Risk\_level\_5\_by\_5)&& (Risk\_level\_5\_by\_5 < 17);

Result\_3 = ['The Risk level of this hazard is ', num2str(Risk\_level\_5\_by\_5), ' ',...  
'Score 15-16: Very High Level, Action Required! recommending reduce the level and report to the facility with Caution.'];

disp(Result\_3);

```
else
    Result_3 = ['The Risk level of this hazard is ', num2str(Risk_level_5_by_5), '!',...
    'Score 20-25: Extreme Level! Do Not Fly! Immediate Action Required! Report to the facility and seek
actions.'];
    disp(Result_3);
end
%
%publish('matrix_5_5_only_prototype_1.mlx', FigureFormat="jpeg")
%path = export("matrix_5_5_only_prototype_1.mlx", "C:\Users\fhr19\Desktop\test1.pdf" )%,
FigureFormat="pdf")
%Notice: The destination of the file will be based on acutal users'
%preference.
%Please edit the destination for the saved file if conducting Step 6
```