Principal Investigator:
Dr. Kendrik Yan Hong Lim

Aviation Virtual Pte Ltd.

AI-Chatbot Research Project Proposal

1. Title of Project

Gen-AI Conversational Training Program Using Retrieval Augmented Generation (RAG).

Keywords

Large Language Models; Retrieval Augmented Generation; Disruption Management, Human Factors; Workforce Training;

2a. Amount of Funding Requested (S$): 200,000.00

2b. Duration of Project (Years): 1

2c. Proposed Start and End Dates: 03 Apr 2025 to 02 Apr 2026.

3. Investigators and Collaborators

Principal Investigator

Name: Lim Yan Hong Kendrik
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Collaborator

Name: Xia Ziqing
School: School of Mechanical and Aerospace Engineering
Institution: Nanyang Technological University
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4. Declaration of Ethics Consideration

Declaration of Ethics Consideration	Yes	No
Human subject	√	
Use of Human Tissues or Cells		√
Animal Experimentation		√
Use of Animal Tissues or Cells		√
Requirement for containment		√

5. Abstract of the Proposal

Training in specialized fields demands extensive onboarding and refresher programs, yet current instructor-led and peer-based methods are resource-intensive, inconsistent, and lack scalability due to variations in trainer expertise and engagement. This study proposes a Retrieval-Augmented Generation (RAG) -enabled Generative AI (Gen-AI) chatbot to deliver a scalable, structured, and adaptive conversational training solution.

The chatbot system offers three proficiency levels (Basic, Intermediate, and Advanced), scenario-based simulations, real-time feedback, and adaptive learning paths, accessible through an intuitive user interface. By leveraging RAG, the chatbot ensures consistent training quality, personalized learning experiences, and the ability to simulate complex, real-world interactions dynamically.

Trainers can evaluate trainee performance, review chat interactions, and grade responses while trainees engage in immersive, role-specific conversational exercises. This AI-driven approach enhances training efficiency, standardization, and preparedness, significantly reducing reliance on resource-heavy methods while addressing gaps in traditional training paradigms.

6. Details of Research Proposal

Problem Statement

Effective radio communications training is essential across specialized fields, yet current onboarding and refresher programs are time-consuming and resource-intensive. Traditional training methods rely on instructor supervision, leading to variability in training quality due to instructor bias and personal teaching styles. This challenge is particularly evident in the bus service industry, where bus captains must frequently communicate with HQ control rooms to report road conditions and incidents. Inconsistent training can result

in miscommunication, operational inefficiencies, and compromised situational awareness, highlighting the need for a scalable and standardized training solution.

Research Gaps

1. Scalability and accessibility

Traditional instructor-led training is resource-intensive and constrained by the availability of skilled trainers. Peer-to-peer training, while an alternative, often results in inconsistencies due to varying trainee competencies and engagement levels. As such, a scalable solution is required to ensure uniform training standards and access without over-reliance on human instructors.

2. Consistent training quality

The effectiveness of training is highly dependent on the experience and engagement of trainers, leading to inconsistencies in learning outcomes. Peer-to-peer methods may fail to cover all necessary scenarios comprehensively, resulting in gaps in preparedness and operational efficiency.

3. Personalized feedback and adaptation

Existing training approaches lack dynamic adaptation to individual learning styles and performance. Without real-time feedback and tailored learning pathways, trainees may struggle to reinforce key concepts effectively, leading to slower skill acquisition and reduced confidence in communication.

4. Handing complex, dynamic situations

Simulating realistic, high-pressure scenarios remains a challenge in traditional training methods. Many existing programs fail to expose trainees to the full spectrum of possible incidents, limiting their ability to develop critical decision-making and response skills in unpredictable situations.

Proposed Methodology/ Solution

This study proposes a Generative AI-based conversational training program designed to train and evaluate SBS trainees. The system will leverage Retrieval-Augmented Generation (RAG) to deliver a comprehensive, adaptive, and personalized learning experience, enhancing training efficiency while maintaining scalability and consistency.

Stakeholders and System Functionality

As illustrated in Figure 1, the system involves two primary stakeholders:

- Instructors: Responsible for training, evaluating scenario-based engagements, and grading trainee performance.
- Trainees: Assume bus driver or HQ operator roles, engaging in conversational

training with the AI chatbot. Their performance is assessed based on response accuracy, adherence to protocols, and communication effectiveness.

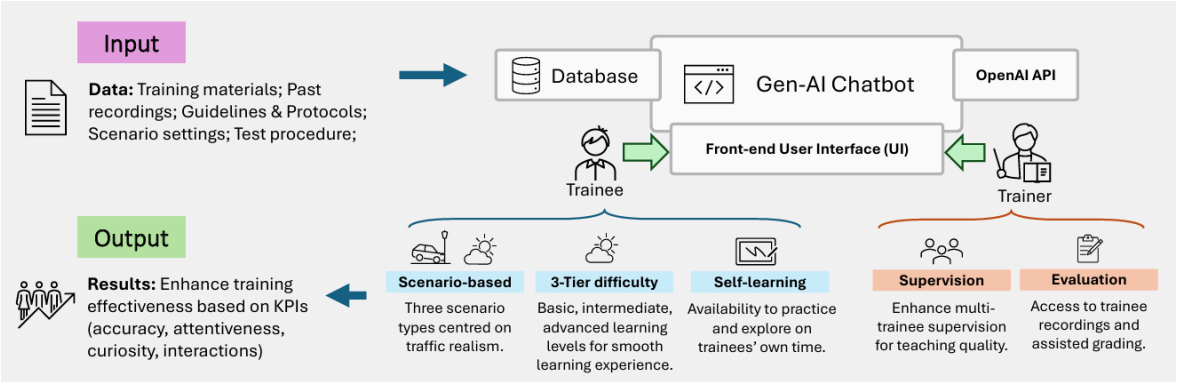

Figure 1: Overview of AI-Chatbot functionalities.

System Framework and Development

The chatbot system is designed as a functional and deployable training solution with a focus on reliability and practical applicability. To validate the effectiveness of the RAG model, the prototype integrates existing open-source tools and solutions within a user-friendly interface.

As shown in Figure 2, the framework outlines the process flow of the chatbot system, illustrating how it retrieves, processes, and generates responses tailored to the training context. The chatbot interacts dynamically with trainees, adapting to different learning levels and providing corrective feedback in real time.

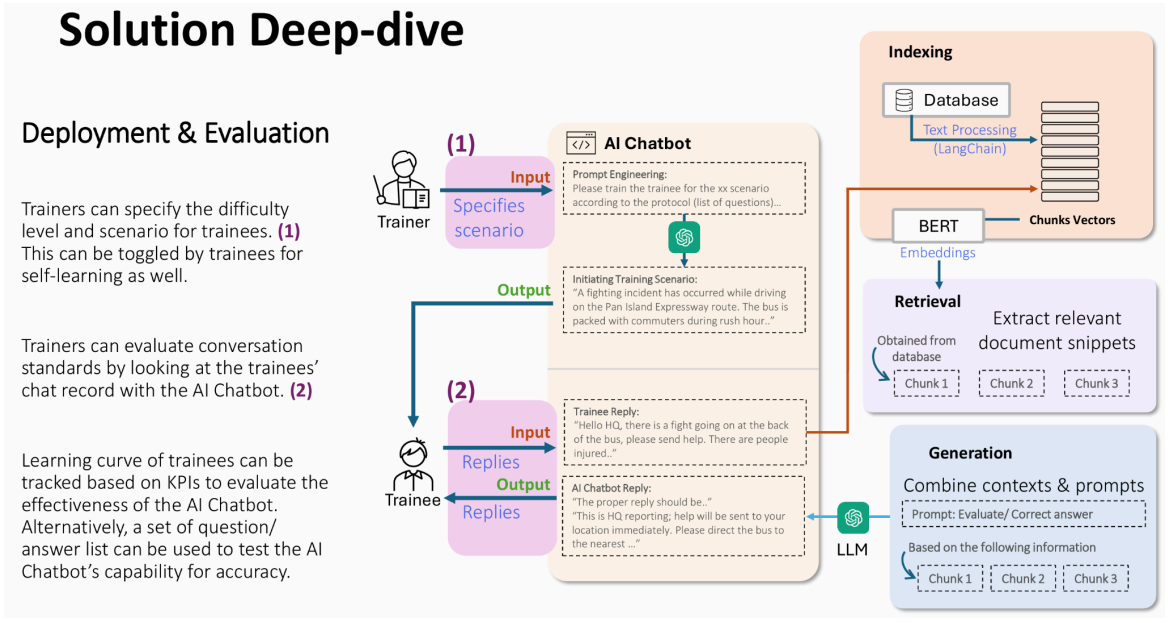

Figure 2: Framework of prototype Chatbot system.

Project Objectives

This project aims to achieve the following key objectives:

- Multi-Level Learning: Implement three difficulty levels (Basic, Intermediate, Advanced) to enhance the learning experience progressively.
- Data-Driven Training: Utilize trainer evaluation metrics and past training recordings to improve training accuracy and contextual relevance.
- User-Friendly Interface: Develop an intuitive UI for both trainees and trainers to ensure ease of use and efficient navigation.
- Scenario-Based Training: Incorporate realistic training scenarios for specialized recaps, incident handling, and situational retraining.

Prototype Development Scope

The initial proof-of-concept (POC) will focus on delivering a functional AI chatbot with a high degree of accuracy. The primary goal is to demonstrate the feasibility of the RAG-powered chatbot for structured conversational training.

As depicted in Figures 3 and 4, the system features distinct interfaces for trainees and instructors:

- Trainee Interface (Figure 3): Provides scenario prompts, real-time AI-generated feedback, and an interactive chat window for training exercises.
- Instructor Interface (Figure 4): Includes a dashboard for monitoring trainee progress, reviewing chat records, and assigning scenario-based training modules.

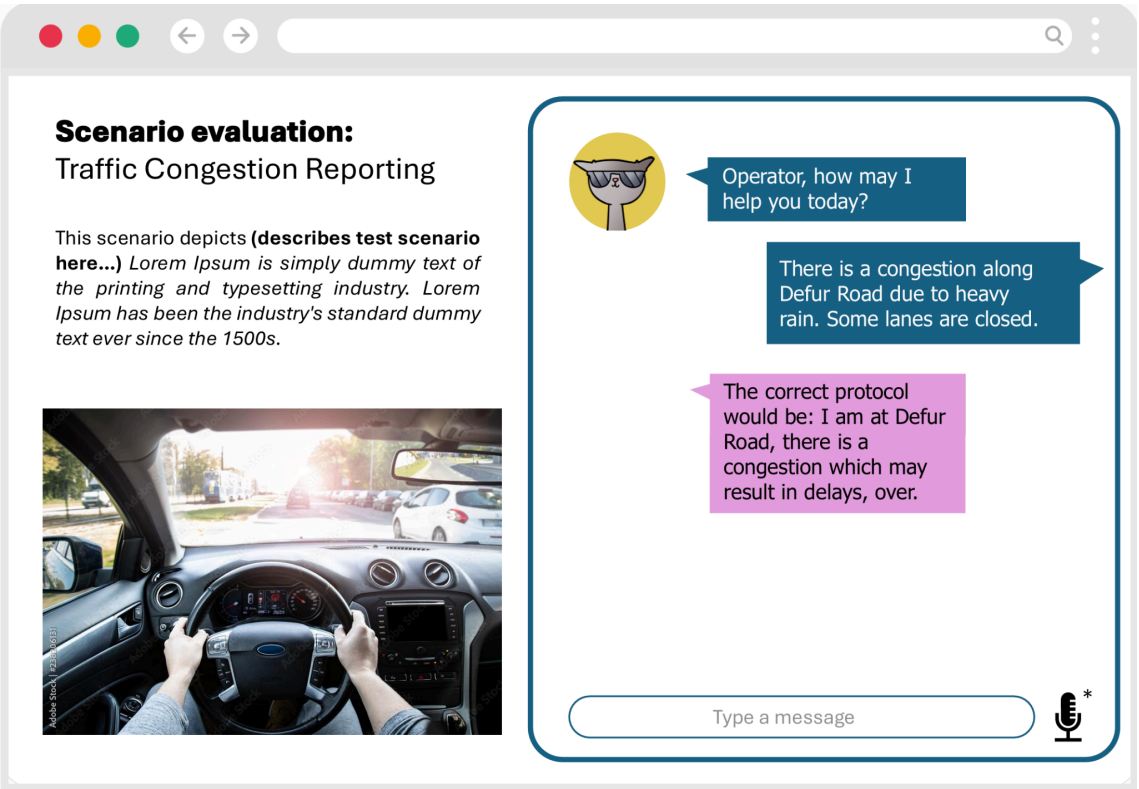

Figure 2: Interface as seen by a trainee.

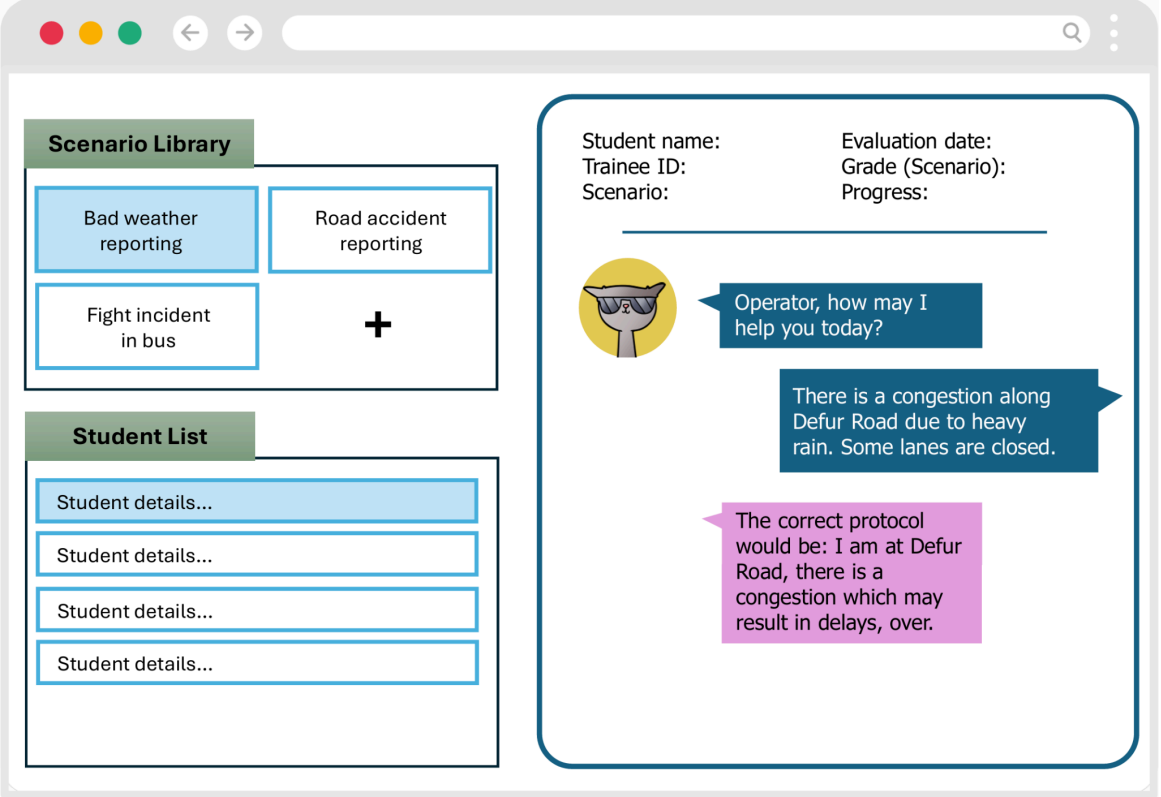

Figure 3: Interface as seen by an instructor.

By integrating RAG-based retrieval, personalized adaptation, and real-time evaluation, this solution aims to bridge existing training gaps, reduce reliance on resource-intensive methods, and provide a scalable, high-quality training experience for specialized radio communications.

Data Requirements/ Required Resources

The accuracy of the Chatbot is highly dependent on the quality, completeness, and relevance of the training data provided. Its effectiveness in delivering accurate responses, simulating realistic scenarios, and adapting to trainees' learning needs relies on well-structured training materials, past recordings, evaluation metrics, and standardized communication protocols. Insufficient or low-quality data may hinder the chatbot's ability to generate precise, context-aware responses, ultimately impacting the system's reliability and training effectiveness. Therefore, ensuring access to high-quality, domain-specific data is critical to achieving the desired learning outcomes and validating the feasibility of this AI-driven training solution.

1. Training materials, Standard Operating Procedures, etc.

2. Past training recordings, evaluation metrics, etc.

Solution Requirements

The primary goal of this project is to develop a high-accuracy, AI-driven conversational training chatbot. To ensure its effectiveness, human-driven experiments will be conducted to test and evaluate system performance alongside benchmark metrics that assess usability, accuracy, and the chatbot's ability to deliver intuitive interactions.

Objectives:

- Scalable and Accessible Training: Develop a 24/7 available chatbot that ensures consistent training standards and allows seamless content updates.
- Knowledge-Driven Conversational Training: Implement a RAG-enabled chatbot capable of retrieving relevant and accurate training scenarios from a structured knowledge base, enhancing trainees' conversational experiences.
- Personalized Feedback and Adaptation: Enable the chatbot to dynamically adapt to trainee responses and performance in real time, providing personalized feedback to optimize learning outcomes.
- Realistic Scenario Simulation: Ensure the chatbot can simulate diverse and complex scenarios using dynamic, up-to-date information, preparing trainees through immersive, realistic experiences.

<u>Chatbot Model Requirements</u>

- Domain-Specific Understanding: The chatbot must accurately process and apply communication standards, including callsigns and protocols (e.g., "over").
- High Accuracy and Consistency: Unlike rigid rule-based systems, the chatbot should function as a dynamic model with an accuracy target of 95% or higher to ensure consistency in responses.
- Lightweight UI and Scalable Backend: A minimalist front-end interface will be developed for usability testing, while the backend will be hosted on a local/cloud server for scalability and future integration.
- Text-Based Interaction: The initial proof-of-concept (POC) will focus on written communication only, excluding voice conversion, virtual environments, or other immersive features in this phase.
- Data-Driven Training: The chatbot will require text-based training data, including real-life voice recordings (converted to text), training documentation, best practice templates, and high-quality artificially generated examples to improve model robustness.

By meeting these requirements, the chatbot will bridge existing training gaps, enhance learning efficiency, and ensure adaptability to real-world operational scenarios, ultimately improving the quality and scalability of specialized communications training.

In-Scope/ Out-of-Scope

In-Scope

- Basic UI for user testing and prototype demonstration.
- Benchmark the RAG Chatbot model against commercial solutions.
- Develop 2 related scenarios for conversational training.

Out-of-Scope

- Capabilities related to Voice-to-Chat or vice versa.
- XR-related functionalities in the solution.
- Avatar features and advanced front-end integration.

Solution Benefits/ Novelty of Innovation

This project introduces unique innovations that differentiate it from existing market solutions, offering enhanced accuracy, efficiency, and scalability in specialized conversational training.

1. Accuracy verification

The AI chatbot's effectiveness and accuracy can be empirically validated through a structured testing dataset and instructor-led supervision of trainee performance. This ensures that training outcomes meet industry standards while maintaining consistent quality across different training scenarios.

2. Project impact

Trainees complete training more efficiently, acquiring higher communication standards and increased confidence in real-world interactions. Scenario-based learning enhances retention and prepares trainees for dynamic, real-life situations.

3. Business impact

Reduced training time allows organizations to deploy competent trainees faster, optimizing cost efficiency while maintaining high standards. Minimizes reliance on resource-intensive instructor-led programs, enabling scalability across multiple locations without compromising training effectiveness.

4. Technology impact

The prototype AI chatbot serves as a foundational system that can later be integrated with VR-based scenario visualization, enabling immersive and interactive training experiences. The RAG-powered AI model offers an adaptive and evolving learning framework, ensuring training materials remain up-to-date and contextually relevant.

Combining retrieval-augmented generation (RAG), adaptive feedback mechanisms, and scalability, critical gaps are bridged in specialised training, offering an improved, data-driven learning platform that improves efficiency, accuracy, and accessibility.

Investigator

Principal Investigator - Dr. Kendrik Yan Hong Lim

Dr. Kendrik Yan Hong Lim is currently a Postdoctoral Fellow at the Massachusetts Institute of Technology (MIT), USA, specializing in industrial AI systems. He holds a PhD and a Bachelor's degree in Mechanical and Aerospace Engineering from Nanyang Technological University and a Master's degree in Industrial Systems Design from Chiba University, Japan, under a Government Scholarship. His research interests include digital twins, knowledge graphs, and engineering informatics. During his experience with Singapore's Agency of Science, Technology and Research, he has been the principal investigator of several research projects in the areas of human-centric AI systems. Active in international conferences and workshops, Dr. Kendrik enjoys robust working relationships with academics of this particular research across the continents. He looks forward to driving this significant project, aiming to contribute to academia, industry, and Singapore.

Collaborator - Dr. Xia Ziqing

Ziqing Xia, Ph.D. is a Research Fellow at the Air Traffic Management Research Institute (ATMRI), Nanyang Technological University, Singapore. She holds a Ph.D. in Human Factors Engineering from Nanyang Technological University and a B.Eng. in Industrial Design from Tianjin University. She specializes in human factors, human-AI collaboration, affective computing, and AI-driven user experience research. Her work integrates multimodal data analysis, AI, and experimental research to enhance safety and efficiency in high-stakes environments such as air traffic control and vessel traffic services.

Intellectual Property (IP), Privacy, and Miscellaneous

Background IP

No background IP from either party.

IP from Deliverables

The proposed framework and model developed are the intellectual property of the Principal Investigator. Aviation Virtual can leverage the solution, and further develop the solution to enhance the capabilities and features of the AI-Chatbot within the original industrial case study.

Explicit permission must be obtained from either party before publication and distribution of materials, as well as modification of the solution to adapt to other companies apart from the original industrial use case..

Aviation Virtual Pte Ltd. will provide industry data and relevant knowledge input for the scenario and testing results.

Personal information collected during the workshop will be anonymised, and statistical data will be aggregated before use.

7a. Milestones

Milestones\ Timeline (Month)	Year 1											
	1	2	3	4	5	6	7	8	9	10	11	12
1. Project kickoff, Literature Review, Data collection, scenario finalization.												
2. Data processing, cloud infrastructure setup.												
3. System design, database setup, scenario design.												
4. RAG development, testing and model fine-tuning.												
5. UI design and deployment, hosting, trial run.												
6. Experiment and result interpretation.												
7. Prototype review and stakeholder feedback.												
8. Design of user experiment, finalizing stakeholder.												
9. Conduct interviews and user experiments.												
10. Report, proof-of-concept demo, publication draft.												

7b. Project Deliverables

The proposed project will lead to a conversational AI Chatbot designed to train SBS captains on radio communication techniques. The deliverables for the project are:	
No. of publications	**2** research articles

8. Contributions, Data Privacy, Security, and Intellectual Property

Contributions
Aviation Virtual will be contributing participants for user testing and the venue required for the experiment. The details of resources needed are as follows:

- Participants for prototype testing: Bus captain trainees or bus captains/ trainers with varying experience in radio communication protocols and evaluation metrics.
- Experimental Space: Office space for uninterrupted testing and data collection on user feedback on prototype system.

The PI will coordinate research efforts from SG and US, including prototype development required for the experiment. Additional manpower resources include:

- 1x Final year NTU student (upon successful acceptance).
- 1x MIT student (upon successful acceptance).

Data Privacy
Aviation Virtual Pte Ltd. will provide industry data and relevant knowledge input for the scenario and testing results.

Personal information collected during the workshop will be anonymised, and statistical data will be aggregated before use.

Intellectual Property (IP)
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9a. Proposed Budget Breakdown

Aviation Virtual: Desmond

Item	Qty	Value (S$)	Type
Equipment	NA	NA	-

Manpower Project officer Participant for user study* Intern**	 1 45 2	 60,000.00 - 800.00	In-kind
Consumables Overseas conference travel Conference fees Local transportation Other (Miscellaneous)	2	1500.00 (ea) 800.00 (ea) 100.00 -	Cash
Sub-total (Cash)			4,700.00

** Subject to availability and optional monetary incentives.*
*** Subject to intern availability and suitability to the role.*

PI: Dr. Kendrik Lim

Item	**Qty**	**Value (S$)**	**Type**
Equipment	NA	NA	-
Manpower Postdoctoral Fellow Student assistant	 2 2	 60,000.00 (ea) -	In-kind
Consumables	NA	NA	-
Sub-total (Cash)			0.00

9b. Payment Schedule

Payment will be reimbursed to the PI with valid quotations/ invoices. Written permission will be obtained from Virtual Aviation before any purchase is made.

10. Undertaking by Principal Investigator & Aviation Virtual Pte Ltd.

In signing the Research Collaboration Agreement, the Principal Investigator (PI) and Aviation Virtual Pte Ltd. UNDERTAKE to:

- ensure Aviation Virtual Pte Ltd is acknowledged in all publications;

- ensure that all publications arising from this research project will be forwarded to Aviation Virtual;
- co-operate with Aviation Virtual to develop R&D capabilities in human-centric industry systems;
- obtain approval from Aviation Virtual and the PI before engaging in any commercial activity that will exploit the research findings from this project.

Kendrik Yan Hong Lim  _____ Name and Signature of Principal Investigator Date: 20 Mar 2025	_____ Name and Signature of Person in Charge (Aviation Virtual Pte Ltd.) Date: