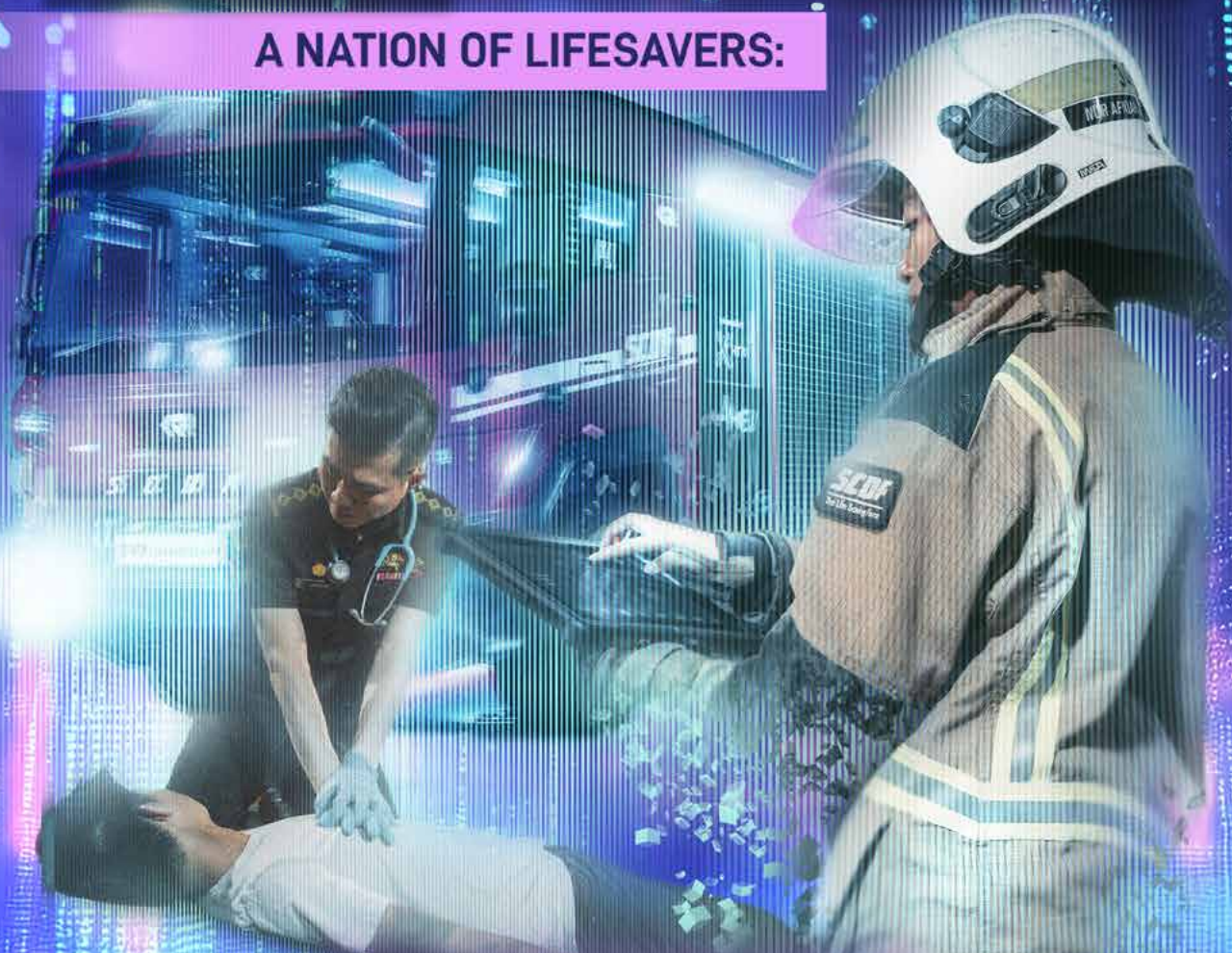


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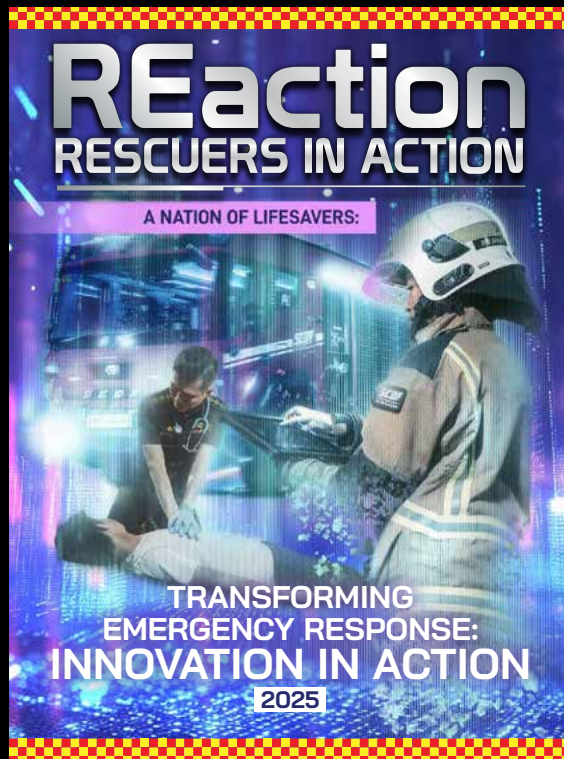
RESCUERS IN ACTION

A NATION OF LIFESAVERS:



TRANSFORMING
EMERGENCY RESPONSE:
INNOVATION IN ACTION

2025



REaction

'REaction — Rescuers in Action' is SCDF's annual technical publication that aims to be a platform for thought-provoking discussions by sharing knowledge and case studies.

The publication provides an array of articles covering a myriad of subjects, as we envision it to be a repository of knowledge for both academic and practising readers in the emergency services fraternity. We hope that you have gained new insight and found REaction beneficial to you.



SCDF

The Life Saving Force

...for a safer Singapore

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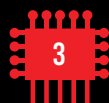
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EDITOR'S FOREWORD

Welcome to this edition of REaction, where we delve into this year's theme: "Transforming Emergency Response: Innovation in Action". This issue showcases how the Singapore Civil Defence Force (SCDF) is harnessing cutting-edge technology and pioneering smart solutions to forge ahead in our transformation journey, setting new standards in emergency response and preparedness.

At the heart of our digital transformation lies the pioneering Microsoft Power Apps Digital Factory initiative, which exemplifies our dedication to streamlining processes and enhancing operational efficiency. This digital evolution extends to our fire safety regime through the Targeted On-site Inspection Tool, representing a significant leap forward in data-driven decision-making. Further advancing our technological capabilities, we examine the implementation of AI-Based Recognition of Hazmat Warning Labels, a system showcasing how artificial intelligence enhances border screening efficiency and resource allocation.

Our frontline personnel's safety and operational effectiveness remain the cornerstone of our transformational journey. The introduction of the Next Generation Self-Contained Breathing Apparatus, featuring state-of-the-art telemetry capabilities, enables real-time monitoring of our emergency responders. Complementing this advancement, our research into innovative Firefighting Hose Handling Techniques demonstrates our continued commitment to enhancing operational safety and effectiveness.

Mental resilience also forms a crucial pillar of our emergency force. Our comprehensive study on Online Resilience Training Interventions addresses the unique mental health challenges faced by our paramedics, particularly in the post-pandemic landscape. This research provides valuable insights into fortifying the psychological foundation of our frontline heroes.

Additionally, we are proud to spotlight SCDF's continued excellence with our 2025 International Search and Rescue Advisory Group External Reclassification. This article showcases the innovative approaches and initiatives that maintain our world-class urban search and rescue capabilities. This milestone reaffirms our position as a leading emergency response force globally.

This edition of REaction stands as a testament to our transformation journey and progress towards SCDF's vision of being "prepared, even for the unexpected". We extend our heartfelt appreciation to all authors and contributors of REaction 2025.

Stay safe and keep well.

REaction Editorial Team
Singapore Civil Defence Force

SCDF-HTX DIGITAL FACTORY: ACCELERATING SCDF'S DIGITAL TRANSFORMATION WITH MICROSOFT POWER PLATFORM

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EDITORIAL PREVIEW

Digital Factory (DF), a joint initiative between the Singapore Civil Defence Force (SCDF) and Home Team Science and Technology Agency (HTX), commenced operations in April 2024. Since then, it has emerged as an integral component of the organisation's digital transformation strategy. Developed in accordance with recommendations set forth in the 2022 Digital Transformation Consultancy Study, this initiative successfully optimised enterprise application development using Microsoft Power Platform and Dynamics 365.

In its initial six-month operational period, DF achieved a significant milestone. It successfully deployed the Global Engagement Management System (GEMS) while continuing to develop new capabilities for SCDF's applications. This demonstrates DF's effectiveness in rapid development to advance SCDF's digital transformation.

DF functions through a dynamic cross-functional team comprising SCDF officers, HTX personnel, and in-house resources. The initiative's demonstrated success has facilitated expansion plans, including the establishment of three additional capacity teams. The three teams would be dedicated to application development, artificial intelligence (AI) solutions, and data architecture and governance, respectively.

Looking ahead, SCDF aims to integrate advanced AI technologies like AI chatbots while working towards a SuperApps ecosystem — a unified digital platform for accessing all digital solutions. This will mark a significant step in SCDF's digital transformation.

INTRODUCTION

In an era where digital transformation is optimising organisations' processes worldwide, the Singapore Civil Defence Force (SCDF) has taken a bold step forward with its Digital Factory (DF) initiative. Launched in April 2024, this innovative venture has already demonstrated remarkable success in revolutionising how the organisation develops and deploys digital solutions. Leveraging Microsoft Power Platform (MPP) and Dynamics 365, DF embodies SCDF's commitment to embracing digital innovation while maintaining operational excellence. As SCDF continues to evolve in an increasingly digital landscape, DF highlights the organisation's forward-thinking approach in leveraging technology to enhance operational and administrative processes.

EARLY SUCCESS AND IMPACT

DF hit the ground running, achieving remarkable results in its first six months of operation. Its flagship product, the Global Engagement Management System (GEMS), was successfully launched during this period, and it transformed how SCDF manages its engagement activities and events. On top of that, DF has catalysed a broader cultural shift towards digital adoption across the organisation. By focusing on actual user needs and operational requirements rather than predetermined specifications, DF was able to evolve responsively.

SCDF ENTERPRISE APPLICATIONS

Through DF, SCDF has transformed manual and repetitive processes into efficient digital solutions. Key applications include:

- 1. Automated Duty Assignment (ADA) App:** Revolutionises roster planning for SCDF frontliners by automatically matching qualified personnel to vehicle requirements. The system uses integrated individual profiles to ensure appropriate staffing whilst enabling real-time updates and emergency roster adjustments. This significantly improves operational readiness.
- 2. Duty Officer Rostering App (DORA):** Streamlines duty scheduling for non-frontline SCDF officers through an intuitive mobile interface. Key features include a calendar view of individual regimental duties, real-time duty swaps, and push notifications. The application has transformed the traditional manual rostersing process into an efficient digital workflow while maintaining comprehensive historical data for audit purposes.
- 3. Food Indentation and Consumption App (FICA):** Transformed food management within Civil Defence Academy units by reducing food wastage through improved planning and real-time consumption tracking. The application streamlines vendor communications and generates valuable analytics for menu planning and cost optimisation. It ensures efficient resource utilisation all around.
- 4. Interactive Troubleshooting App (ITA):** Serves as a comprehensive mobile guide for vehicle maintenance, featuring step-by-step guidance on common vehicle-related issues. With direct access to troubleshooting guides and communications with the vendors, the application has significantly reduced vehicle downtime and improved SCDF's appliance readiness.
- 5. Global Engagement Management System (GEMS):** Transformed SCDF's event and visit management through an end-to-end structured planning workflow. The system enables lead officers to efficiently manage the entire planning process through automated task routing, real-time updates, and streamlined stakeholder communications. Moreover, the system is supported by a comprehensive analytics dashboard that provides engagement metrics.
- 6. Management Connect:** Leverages built-in Microsoft Teams to create a unified communication channel for all SCDF personnel. The platform facilitates closer outreach to SCDF personnel, supports multimedia content distribution, and provides valuable analytics on message engagement. It ensures effective information dissemination across the organisation.



Figure 1: Screenshot from ADA



Figure 2: Screenshot from DORA

7. **Building Inspection Appointment Booking App:** Transformed the inspection scheduling process for qualified persons. With features including automated reminders, real-time availability updates, and comprehensive inspection history tracking, the app has significantly reduced project delays and improved operational efficiency.
8. **Product Listing Scheme Verification Bot:** Automates routine verification tasks for Temporary Fire Permits and Fire Safety Certificates. By reducing processing time and incorporating built-in compliance checking and automated audit reports, the bot has significantly streamlined the verification process while maintaining high accuracy standards.
9. **Responders Functional Fitness Test App:** Provides test conductors with a digital platform to capture participants' results, enabling comprehensive data presentation, long-term retention, and analysis.
10. **Basic Task Manual App:** Serves as a centralised mobile portal offering frontliners instant access to Basic Training Manuals, which contain essential functional procedures.
11. **REDCON:** Enables real-time REDCON status for SCDF units and forces, with automated updates pushed to commanders.
12. **SCDF AI Assistant:** An AI chatbot exclusively designed for the SCDF workforce. It provides seamless integration to SCDF-wide information residing within SCDF Wiki. This enables Fire Rescue Specialists, Emergency Medical Services personnel, and other SCDF officers to instantly retrieve information through natural language queries.

THE PLATFORM ADVANTAGE

SCDF's decision to leverage MPP has proven instrumental in enhancing its digital capabilities. The platform, now capable of handling data classified up to Restricted/Sensitive-Normal, provides a robust foundation for rapid application development. Key advantages include:

1. **Technical Capabilities:** The low-code development environment enables rapid prototyping, while seamless integration with the existing Microsoft ecosystem supports smooth operations. Advanced automation capabilities through Power Automate, coupled with built-in analytics and reporting tools, have significantly enhanced operational efficiency.
2. **Security Features:** Security is a cornerstone of the platform's success. Its implementation of role-based access control and end-to-end encryption protects sensitive data while regular security updates and patches maintain system integrity without affecting user performance. Additionally, comprehensive audit logging ensures compliance tracking. These security measures have enabled confident adoption across all levels of the organisation.
3. **Cost and Efficiency Benefits:** The platform has delivered substantial cost and efficiency benefits; it has significantly reduced development time and costs compared to traditional methods. Its familiar interface minimised training requirements, while its scalable licensing model ensures sustainable growth. Lower maintenance overhead has further contributed to the platform's overall cost effectiveness, making it a financially sound choice for SCDF's digital transformation journey.
4. **Integration Capabilities:** Integration capabilities have proven particularly valuable. The platform enables seamless connection with SCDF's existing systems and facilitates real-time data synchronisation. This integration success extends across various domains, from HR systems to emergency response platforms, creating a cohesive digital ecosystem that enhances operational efficiency and decision-making capabilities.

CROSS-FUNCTIONAL COLLABORATION AND EXPERTISE

DF will operate under the guidance of an Executive Steering Committee, chaired by the Deputy Commissioner of Future Technology and Public Safety. The committee, comprising representatives from SCDF and HTX Civil Defence Programme Management Centre (CDPMC), will meet fortnightly to provide strategic oversight, address challenges, and establish priorities for application development and resource allocation. At the operational level, HTX CDPMC will oversee the Capacity Team's daily activities, including stakeholder stand-up discussions and technical guidance. SCDF's Transformation and Future Technology Department (TFTD) will maintain oversight of project deliverables and timelines.

DF operates with a well-structured cross-functional team comprising officers from SCDF lead departments, TFTD, HTX CDPMC, and frontline units. This multi-disciplinary approach bridges the gap between operational needs and technological solutions.

The development layer comprises solution architects who design robust system integrations, technical consultants responsible for development and implementation, business analysts who gather requirements and liaise with users, and quality assurance specialists who ensure system reliability. This technical team works in close coordination to deliver solutions that meet both technical standards and user needs.

The user layer forms the crucial bridge between technology and operations. Department representatives provide domain expertise, end-user champions conduct ground testing and feedback collection, and citizen developers drive innovation through local solutions.

This multi-layered approach ensures that digital solutions remain grounded in operational realities while pushing the boundaries of innovation.

CHANGE MANAGEMENT AND USER ADOPTION STRATEGIES

DF follows a comprehensive change management framework developed by TFTD that addresses the human aspect of digital transformation. Stakeholder engagement forms the foundation of this approach. Town halls and feedback sessions are conducted regularly to ensure continuous communication. During these sessions, department-level digital champions serve as local experts and advocates, while monthly user group meetings provide forums for discussion and improvement. Complementing these efforts, digital transformation newsletters keep all personnel informed of progress and upcoming changes.

To ensure personnel at all levels can effectively utilise new digital solutions, training and development programmes are provided. Structured onboarding programmes introduce new users to the systems, while regular skill upgrading workshops maintain and enhance digital competencies. Additionally, online learning resources provide flexible learning options, and peer mentoring systems encourage knowledge sharing across the organisation.

The success of these initiatives is carefully monitored through various tracking mechanisms. Monthly usage analytics provide insights into system utilisation, while user satisfaction surveys gather feedback on solution effectiveness. Feature utilisation tracking helps identify areas for improvement, and performance improvement measurements quantify the impact of digital transformation on operational efficiency.

A robust support framework underpins the entire change management process. A 24/7 technical helpdesk provides immediate assistance for urgent issues, while a comprehensive self-help knowledge base enables users to resolve common problems independently. Further, regular system health checks ensure consistent performance, and user feedback loops drive continuous improvement.

GROWING MOMENTUM AND EXPANSION

The success of DF has catalysed broader interest in digitalisation across SCDF. The Digital Frontliner 2.0 event in August 2024 particularly sparked enthusiasm among both frontline officers and staff department personnel. It generated numerous potential use cases for digital solutions.



Figure 3: SCDF, HTX CDPMC, and Microsoft Senior Management at Digital Frontliner 2.0

This growing demand has driven plans to expand DF's capabilities through three additional capacity teams, each focusing on specific aspects of digital transformation.



Figure 4: SCDF-HTX DF capacity teams with focus on specific aspects

The first and second capacity teams will focus on enterprise application development. They will be involved in enhancing user experience through improved interface design and cross-platform compatibility. Their work encompasses developing robust offline functionality for critical applications and optimising performance across various devices and network conditions. This team's efforts will ensure that SCDF's digital solutions remain accessible and effective in all operational scenarios.

The third capacity team will specialise in AI solutions implementation on the Azure AI platform. Their scope includes developing sophisticated chatbot systems for internal support, implementing predictive analytics for resource optimisation, and integrating machine learning capabilities for enhanced decision-making. Natural language processing features will facilitate more intuitive interaction with digital systems, making them more accessible to all users.

The fourth capacity team will concentrate on establishing comprehensive data governance frameworks. This team oversees the development and implementation of data quality standards, security protocols, and compliance monitoring systems. Their work will ensure that SCDF's digital transformation maintains the highest standards of data integrity while enabling powerful analytics capabilities for informed decision-making.

EMPOWERING GROUND-UP INNOVATION

A distinctive feature of DF is its emphasis on ground-up innovation through the Citizen Developers programme. This initiative identifies and nurtures frontline officers with potential and interest in mobile application development. Identified officers will undergo training by Microsoft professionals to create proof-of-concept enterprise applications or software solutions using the Microsoft suite before transitioning the project to DF. In this manner, digital solutions remain rooted in operational realities and user needs.

FUTURE VISION AND INTEGRATION OF AI CAPABILITIES

Looking ahead, SCDF is pursuing an ambitious roadmap for technological advancement. The integration of AI technologies stands at the forefront of this vision, with plans to implement smart resource allocation systems that optimise the deployment of personnel and equipment. Predictive maintenance capabilities will enhance equipment reliability, while automated report generation will reduce administrative burden. Additionally, virtual assistance systems will provide real-time support to officers, enhancing operational efficiency and decision-making capabilities.

The SuperApps ecosystem SCDF is working towards represents a cornerstone of its digital future. This unified platform will serve as a single touchpoint for officers to access all digital solutions developed using MPP. The system will feature seamless authentication across applications, streamlined cross-application workflows, and integrated dashboards providing comprehensive operational visibility. Personalised user experiences will ensure that each officer has efficient access to the tools and information most relevant to their role.

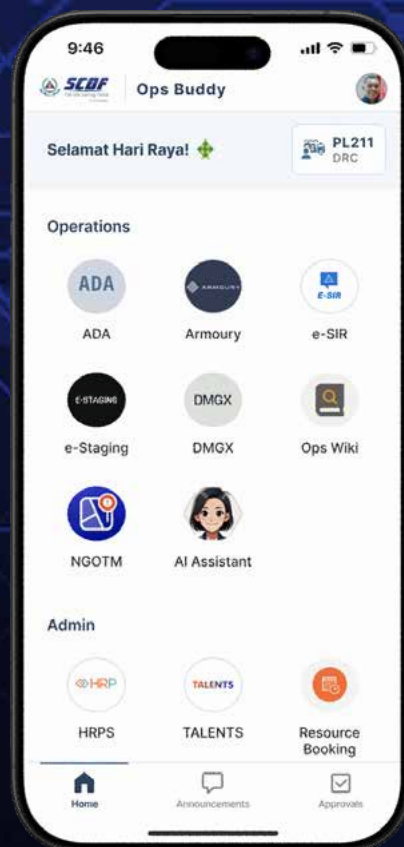


Figure 5: Artist impression of SCDF's SuperApps

CONCLUSION

SCDF-HTX's DF, since its inception in April 2024, has proven to be a transformative force in SCDF's digital journey. Its success stems from its rapid development capabilities, effective stakeholder collaboration through cross-functional teams, data-driven decision-making enhanced by robust governance frameworks, and cultural transformation. The successful Citizen Developers programme evidences this.

SCDF's commitment to digital innovation is underscored by plans to expand DF's capabilities through three additional capacity teams covering mobile applications, AI solutions, and data governance, respectively. As DF continues to evolve, it not only enhances SCDF's operational and administrative efficiency but also sets a benchmark for digital transformation among the Whole-of-Government agencies.

TRANSFORMING FIRE SAFETY INSPECTIONS WITH THE TARGETED ON-SITE INSPECTION TOOL

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EDITORIAL PREVIEW

The Singapore Civil Defence Force (SCDF) is poised to transform fire safety inspections with its innovative Targeted On-site Inspection Tool (TOIT), a cornerstone of the Intelligent Core (iCORE) development. Operational across all frontline units since April 2025, TOIT utilises data-driven insights and predictive modelling to identify premises with a higher propensity for fire safety violations. This enables more targeted and efficient inspections.

This groundbreaking system, which has already demonstrated better accuracy in a successful pilot study across five fire stations, aims to enhance overall fire safety outcomes. This would allow SCDF to allocate resources more effectively and address potential hazards promptly.

Moving forward, plans are underway to enhance TOIT by integrating additional datasets and automating the prioritisation of premises with a higher propensity for fire safety violations. TOIT represents the first step towards a broader ecosystem of fire safety management tools, the Fire Safety Copilot, which aims to elevate the state of fire safety compliance across all premises.

REVOLUTIONISING FIRE SAFETY: SINGAPORE'S AI-POWERED INSPECTION SYSTEM

In an era where artificial intelligence (AI) is transforming various aspects of public service, Singapore's Civil Defence Force (SCDF) has unveiled an innovative solution set to revolutionise fire safety inspections. The Targeted On-site Inspection Tool, or TOIT, represents a significant leap forward in how fire safety inspections are conducted. By combining AI with years of accumulated data, it delivers a smarter, more efficient inspection system.

THE CHALLENGE OF MODERN FIRE SAFETY

With over 15,000 fire safety inspections conducted annually across Singapore, ensuring comprehensive coverage while maintaining effectiveness has been a persistent challenge. Traditional methods relied heavily on manual selection and individual judgment, which could vary between officers. This approach, while functional, was not always the most efficient in preventing fire safety violations or identifying recalcitrant offenders. Undetected violations can lead to severe consequences, including loss of life and property damage. Meanwhile, inspecting compliant premises too frequently results in suboptimal resource allocation. There is thus a need for a more targeted approach.

ENTER TOIT: A SMART SOLUTION

TOIT represents a shift from intuition-based to data-driven fire safety inspections. At its core, TOIT is an AI system that analyses various data points to predict which premises are more likely to have fire safety violations. It effectively functions as a highly sophisticated risk assessment tool that can process vast amounts of information far more quickly and accurately than traditional methods. It is envisaged that with TOIT, SCDF would be able to achieve the strategic outcomes of 1) strengthening premises' fire safety compliance, 2) reducing the severity of fires related to violations, and 3) lowering the occurrence of fires involving violations.

HOW TOIT WORKS

TOIT calculates a "propensity score" for each building by analysing multiple factors ("model features"). Past fire safety violations play a crucial role in this calculation, as buildings with a history of violations are more likely to face future issues. The building's inspection history, including scheduled and ad hoc inspections, is equally important. The system also considers the time elapsed since the last inspection, as longer gaps may correlate with increased risk.

In addition, the type of building and its usage patterns also factor into the equation. Certain categories, particularly industrial facilities, have a higher risk of violations. Historical data from similar premises helps establish patterns and trends to identify potentially increased risk.

These elements are then weighted and analysed by TOIT's AI system to create a comprehensive risk assessment that guides inspection priorities.

Table 1 below provides examples of TOIT's key model features.

Table 1: Examples of TOIT's key model features

S/N	Model Feature	Explanation
1	Past violation counts	A higher count of past violation tends to indicate a greater likelihood of future violations.
2	Last violation severity	A history of severe violations tends to indicate a greater likelihood of future violations.
3	Past scheduled inspections	A higher count of past scheduled inspections tends to indicate a greater likelihood of future violations.
4	Past inspection counts	A higher count of past inspections tends to indicate a greater likelihood of future violations.
5	Past ad hoc inspections	A higher count of past ad hoc inspections tends to indicate a greater likelihood of future violations.
6	Days since last inspection	A higher count of days since last inspection tends to indicate a greater likelihood of future violations.
7	Violation rate ¹	A higher violation rate tends to indicate a greater likelihood of future violations.
8	Past NOO counts	A higher count of past Notice of Offence (NOO) ² offences tends to indicate a greater likelihood of future violations.
9	Building category (Industrial)	Certain building category, such as industrial, tends to indicate a greater likelihood of future violations.
10	Past FHAN counts	A higher count of past Fire Hazard Abatement Notice (FHAN) ³ offences tends to indicate a greater likelihood of future violations.

¹ Violation Rate refers to percentage of fire safety inspections at a premises where fire safety violation is encountered.

² Notice of Offence (NOO) requires the responsible entity to follow up with compliance actions to rectify the fire safety offence within a stipulated grace period. Upon rectification, a composition fine will be issued to compound the offence committed.

³ Fire Hazard Abatement Notice (FHAN) is a written warning that requires the responsible entity to take all necessary steps to abate the fire hazard within a stipulated grace period and prevent its recurrence within the premises.

MAKING FIRE SAFETY SMARTER

One of TOIT's most impressive features is its ability to learn and improve over time. As more inspections are conducted and more data are collected, the system's predictions will become increasingly accurate. In initial trials, TOIT has already demonstrated remarkable results. It correctly predicted violations 40% of the time, nearly twice the 14-20% achieved by previous methods. This significant improvement in accuracy, with even greater accuracy expected, allows inspection officers to focus their efforts where they are most needed. This leads to more efficient use of resources and better fire safety outcomes. Figure 1 below illustrates the effectiveness of TOIT in determining premises with violation outcomes.

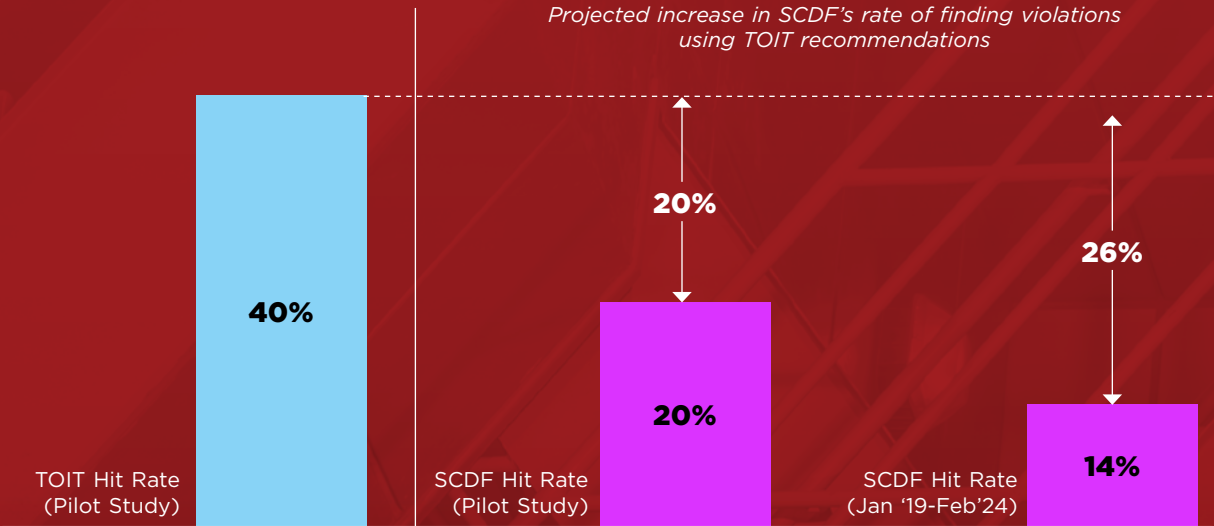


Figure 1: Trial results for TOIT's rate of predicting violations correctly, compared with SCDF's rate of finding violations

The system's success is not limited to specific areas or building types. During the proof-of-concept phase, TOIT showed consistent results across different geographical regions and various building categories. This consistency is crucial for maintaining equitable fire safety standards nationwide.

BEYOND BASIC INSPECTIONS

TOIT's capabilities extend far beyond simply identifying potential violations. The system includes sophisticated scheduling functions that automate inspection planning. It considers factors such as the building's propensity for fire safety violations, the likelihood of enforcement action required (i.e., FHAN vs NOO)⁴, and resource optimisation. This automated scheduling ensures optimal use of manpower by prioritising premises with a higher propensity for fire safety violations. In particular, it focuses on premises more likely to require the issuance of an NOO. At the same time, it maintains inspection coverage of high-risk installations and other priority premises.

⁴ An NOO is issued for fire safety offences or when the contravention is of a more serious nature and warrants a heavier penalty, such as unauthorised change of use of premises. It carries composition fines of up to \$5,000. Court action may be taken against errant parties if they fail to rectify the fire safety offence as required in the NOO. If convicted in Court, the responsible party may be liable to a fine not exceeding \$200,000, imprisonment for up to two years, or both.

Officers using TOIT have access to comprehensive building information through user-friendly dashboards (as shown in Figures 2 and 3 below). These dashboards provide crucial details about each premises, including past inspection records, compliance history, and contact information for building management. This wealth of information allows officers to approach each inspection with a thorough understanding of the premises' history and potential areas of concern.

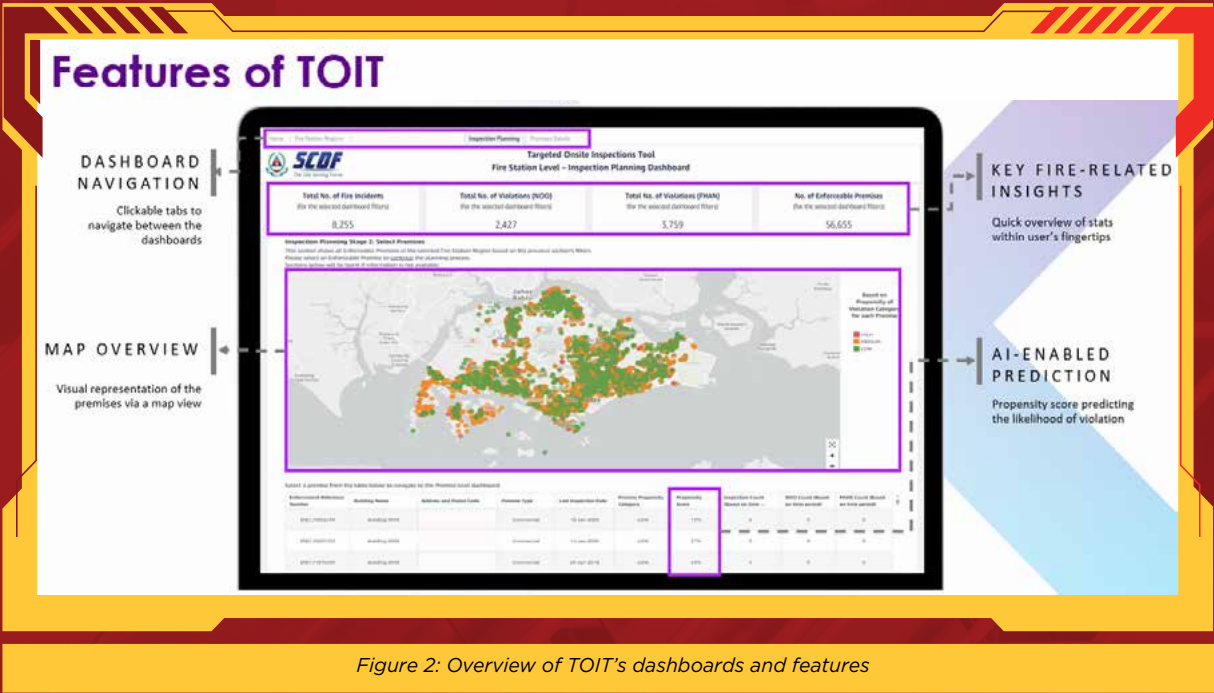


Figure 2: Overview of TOIT's dashboards and features



Figure 3: Dashboard showing an overview of fire stations' boundaries

The system's trend analysis capabilities are particularly valuable for long-term planning and policy development. By identifying patterns in fire safety violations across different building types and areas, TOIT enables SCDF to take a more proactive approach to fire safety. These insights can inform a wide range of efforts, from public education campaigns to policy adjustments, helping to prevent violations before they occur.

THE FUTURE OF FIRE SAFETY INSPECTION

Currently, TOIT works with an auto-scheduler function that incorporates TOIT's recommendations alongside high-risk installations and selected priority premises (such as public entertainment outlets, nursing homes, and waste management companies). This optimises SCDF's approach to managing targeted inspections.

By 2026, TOIT will become part of a larger initiative, the Fire Safety Copilot (FSc). This expanded system will introduce several new features that further enhance the inspection process. For example, a pre-inspection guide will provide officers with detailed information about building layouts and potential areas of interest (such as violation history). Reviewing such information before they arrive on site allows for more targeted and efficient inspections.

The system will also include a Fire Safety AI Assistant, powered by agentic AI and a large language model, to answer dynamic fire safety queries in real time. This support will help ensure consistent standards across all inspections while providing officers with immediate expert assistance. Additionally, an automated tracking system will streamline post-inspection follow-ups to ensure identified violations are properly and promptly rectified.

GLOBAL IMPLICATIONS

For fire safety organisations worldwide, TOIT is an important case study in modernising fire safety inspections. The system's success in integrating data from multiple sources, including internal systems and other government agencies, highlights the importance of robust data sharing frameworks. This integration allows for a more comprehensive understanding of each premises and its potential risks.

Singapore's phased implementation approach provides valuable lessons for other jurisdictions considering similar systems. It begins with a proof of concept, followed by initial operating capability, and then full operating capability. This gradual rollout allows for careful testing and refinement while maintaining operational effectiveness. It also helps identify and address issues early, and allows users time to familiarise themselves with the new system.

The emphasis on measurable outcomes has been crucial to demonstrating TOIT's value. The system tracks clear metrics, including a reduction in fire severity and a decrease in fire safety violation-related incidents. These concrete measures validate the system's effectiveness and provide valuable data for continuous improvement.

REAL-WORLD IMPACT

The system's ability to identify premises with a higher propensity for fire safety violations has led to more timely interventions, which can prevent serious incidents. This proactive approach not only helps prevent potential fires but also encourages building owners and management to take greater responsibility for fire safety compliance. The increased likelihood of inspection at non-compliant premises also creates a strong incentive to maintain proper fire safety standards.

LOOKING AHEAD

As TOIT continues to evolve, it is set to become even more sophisticated. Future enhancements include real-time data integration from various sources, like our Fire Safety Online Processing System. This will allow for even more updated risk assessments and timely follow-ups of re-inspections.

The system will also benefit from improved data sharing with external agencies, such as the Singapore Land Authority and the Accounting and Corporate Regulatory Authority, which will enable more accurate and up-to-date information about buildings and their occupants.

In addition, TOIT's predictive capabilities will be enhanced by incorporating additional environmental factors, such as seasonality and inter-agency datasets. Coverage will also expand to include previously uninspected premises, ensuring more comprehensive fire safety oversight across Singapore.



Figure 4: Collaboration between the Fire Safety Department, Transformation and Future Technology Department, and Home Team Science and Technology Agency to develop TOIT and FSc

CONCLUSION: A MODEL FOR MODERN PUBLIC SAFETY

TOIT represents more than just a technological advancement; it is a model for effectively applying AI to enhance public safety. Its success demonstrates that, when properly implemented, AI can significantly improve the efficiency and effectiveness of essential public services.

TOIT offers valuable insights into the future of fire safety management. Its combination of data analytics, AI, and practical application provides a blueprint for similar initiatives in other agencies and countries. Singapore's success with the system shows that, with the right combination of technology, expertise, and implementation strategy, it is possible to create more efficient and effective fire safety inspection systems that benefit both enforcement agencies and the public.

As cities worldwide become increasingly complex and resource-constrained, solutions like TOIT offer a way forward for smarter, more efficient public safety management. It is a clear example of how technology can be harnessed for tangible improvements in public safety and emergency preparedness. We hope the system's continued progress will inspire similar innovations in public safety worldwide to contribute to safer urban environments for all.

SCDF'S NEXT GENERATION SELF-CONTAINED BREATHING APPARATUS

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EDITORIAL PREVIEW

This comprehensive document examines how the Singapore Civil Defence Force (SCDF) has successfully implemented and adapted the Next Generation Self-Contained Breathing Apparatus. It details how an off-the-shelf product was transformed into an integral part of SCDF's advanced firefighting operations through quick implementation strategies and digital integration initiatives.

INTRODUCTION

The Singapore Civil Defence Force (SCDF) stands at the forefront of firefighting innovation with its revolutionary Next Generation Self-Contained Breathing Apparatus (NG-SCBA). This advanced system represents a quantum leap in firefighting technology as it combines sophisticated telemetry capabilities with enhanced safety features to support frontline operations. The integration of this state-of-the-art equipment marks a pivotal moment in SCDF's commitment to protecting both its personnel and the community they serve.

At the heart of this innovation is the apparatus's ability to transmit critical real-time data to SCDF's monitoring unit. This gives the Breathing Apparatus Control Officer (BACO) unprecedented access to vital information, including real-time monitoring of each firefighter's remaining air supply. This capability enables swift intervention in distress situations, potentially making the crucial difference in life-threatening scenarios.

A key enhancement to the system is the integrated Personnel Distress Device (PDD). Unlike its predecessor, which relied on manual activation, the integrated PDD activates automatically when the air tank is engaged and eliminates the risk of human oversight during emergency deployment. It also provides an additional layer of safety in hazardous conditions through motion-sensing technology, which triggers localised audible alarms and monitoring unit alerts if a firefighter remains motionless.

While the NG-SCBA itself is an advanced off-the-shelf product, SCDF's quick implementation and integration approach has revolutionised firefighting operations. The organisation's ability to rapidly deploy and adapt this technology also showcases its commitment to leveraging cutting-edge solutions for enhanced operational effectiveness.



Figure 1: The NG-SCBA's new features and capabilities

HISTORICAL EVOLUTION AND TECHNOLOGICAL PROGRESS

The journey of firefighting respiratory protection spans over a century of technological advancement. In the earliest days of organised firefighting, personnel relied on rudimentary methods, often nothing more complex than water-soaked cloths pressed against their faces to filter smoke. This basic approach offered minimal protection against the deadly effects of smoke inhalation and toxic gases. Its limitations led to numerous casualties among firefighting personnel.

The dawn of the 20th century brought the first practical SCBA systems, which were inspired by innovations in mining safety and diving equipment. These early systems, though revolutionary for their time, were bulky and limited in their capabilities. The apparatus consisted of heavy metal tanks, basic pressure regulators, and primitive face masks that often provided inconsistent protection. Nevertheless, these early systems marked the beginning of a new era in firefighter safety.



Figure 2: The smoke helmet of the 1900s operated on the same principle as a deep-sea diver's breathing system



Figure 3: The self-contained system of the 1900s comprised an oxygen cylinder and a breathing bag with a carbon dioxide absorbent, allowing carbon dioxide from exhaled air to be removed, mixed with fresh oxygen, and recirculated for reuse

Reference from and photos credit: London Fire Brigade

The post-World War II era was another significant turning point, particularly with the introduction of compressed air systems in the 1960s. This development fundamentally transformed firefighting capabilities as it allowed firefighters to operate in smoke-filled environments for extended periods with greater safety. The technology borrowed heavily from military applications, incorporating improvements in materials science and breathing apparatus design that enhanced both reliability and usability.

SCDF'S IMPLEMENTATION STRATEGY AND SUCCESS

Strategic Selection and Adaptation

SCDF began its journey toward modernising its breathing apparatus capabilities with a rigorous evaluation of available commercial solutions in the global market. The selected NG-SCBA system emerged as the optimal choice not merely for its advanced features, but for its adaptability and integration potential. While the system represents state-of-the-art commercial technology, SCDF's implementation approach transformed it into something far more comprehensive within Singapore's emergency response framework.

The evaluation process involved extensive field testing, technical assessments, and careful consideration of Singapore's unique urban firefighting challenges. High-rise buildings, industrial complexes, and maritime facilities present distinct operational demands that required careful consideration in the selection process. SCDF's technical teams worked closely with operational personnel to ensure the chosen system could meet these specific requirements while maintaining compatibility with existing protocols and equipment.



Figure 4: Testing of the NG-SCBA in the world-class, state-of-the-art facilities in the Civil Defence Academy

Technical Specifications and System Architecture

The NG-SCBA platform incorporates advanced materials, sophisticated electronics, and ergonomic design principles, and the system's physical architecture reflects firefighter needs. It features a revolutionary three-step height adjustment system and an innovative pivoting waist belt that substantially reduces physical strain during prolonged operations.

Central to the system's capabilities is its telemetry ecosystem. The portable telemetry unit, powered by rechargeable nickel-metal hydride batteries, maintains reliable connection within a 1.5 km line of sight, ensuring consistent monitoring during extended operations. Moreover, the system's communication architecture significantly reduces radio traffic through automated status updates while maintaining critical communication capabilities.

The apparatus is also equipped with Internet-of-Things sensors that substantially improve situational awareness through an interconnected network. These sensors monitor various parameters, including air pressure and motion. The data is processed in real-time, providing immediate alerts and updates to both the wearer and command staff. This comprehensive monitoring system constitutes a marked advancement over previous generations of breathing apparatus technology.



Figure 5: Workings of the NG-SCBA telemetry system

OPERATIONAL INTEGRATION AND ADAPTATIONS

Customised Operational Protocols

SCDF has developed specialised protocols that maximise NG-SCBA's capabilities within Singapore's unique emergency response environment. Going beyond the manufacturer's standard operating procedures, these protocols draw on SCDF's extensive experience in urban firefighting.

For instance, the organisation has created specific procedures for high-rise operations that leverage the system's telemetry to improve accountability of personnel across multiple floors. In industrial settings, SCDF has adapted the system's monitoring capabilities to align with its hazardous materials response protocols. This adaptation enables more effective management of personnel exposure times and air consumption rates during chemical incidents. These modifications to SCDF's standard procedures demonstrate its ability to enhance commercial technology through innovative operational applications.

Command and Control Enhancement

The augmentation of the BACO role exemplifies SCDF's innovative approach to technology integration. As digital tools evolve to provide comprehensive monitoring capabilities, BACOs can manage larger teams more effectively while maintaining strict safety protocols. The digital system automatically tracks entry times, air consumption rates, and environmental parameters, enabling more informed decisions about crew rotation and resource allocation.



Figure 6: An SCDF firefighter reading the air pressure of the breathing apparatus cylinder before entering the risk area

TRAINING AND OPERATIONAL EXCELLENCE

Comprehensive Training Framework

SCDF's training programme for the NG-SCBA system represents a significant departure from conventional equipment training approaches. Rather than focusing solely on technical operation, the programme integrates the technology into broader emergency response scenarios. Training modules combine classroom instruction with practical exercises that simulate real-world conditions. This comprehensive approach ensures that personnel are comfortable with both the technology and its application in various operational contexts.

The training framework also includes specialised modules for different roles within the organisation. Command staff receive additional training on data interpretation and resource management, while maintenance personnel undergo extensive technical training to ensure system reliability. This role-specific approach has contributed greatly to the successful integration of the technology across all levels of the organisation.

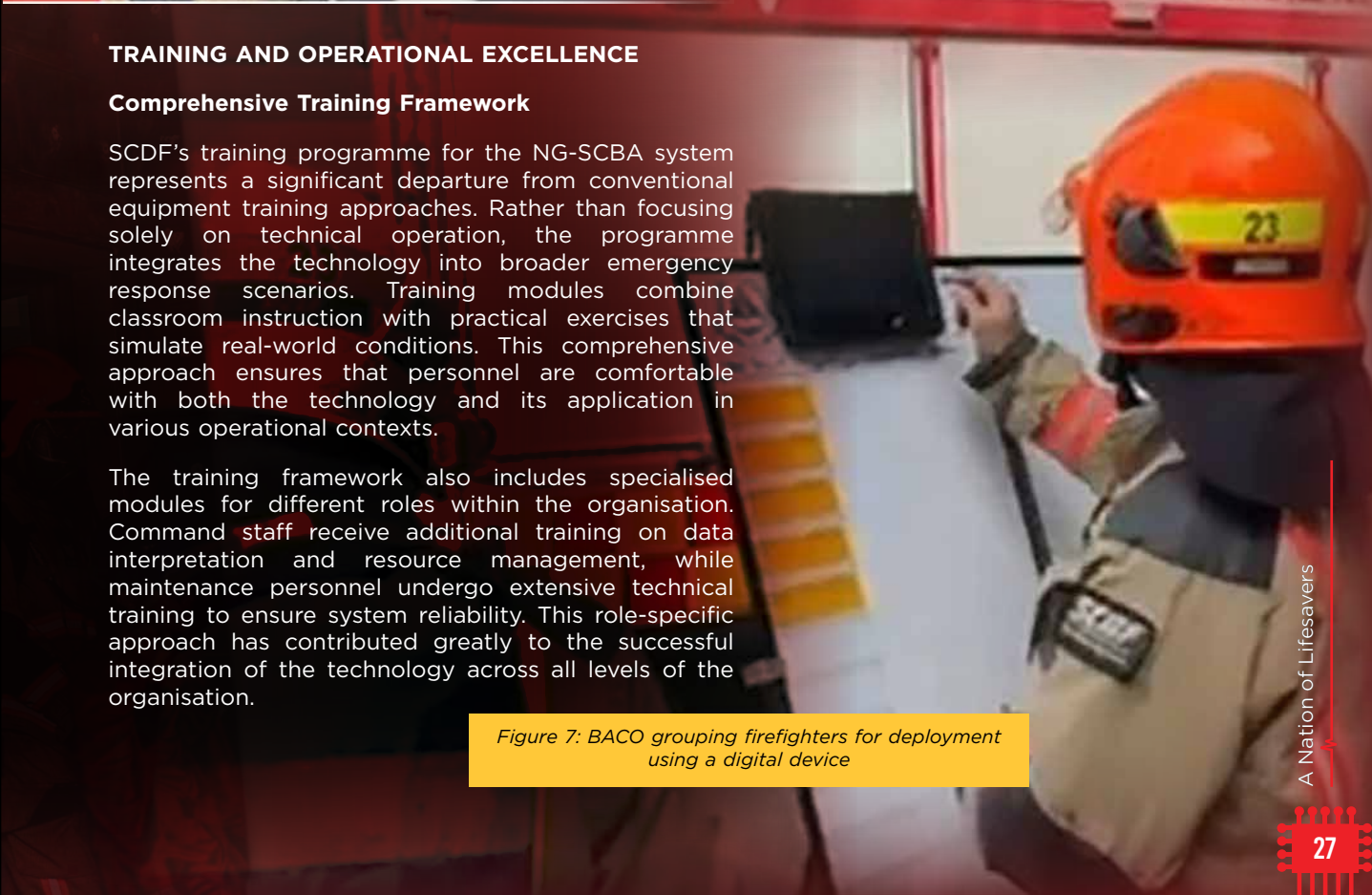


Figure 7: BACO grouping firefighters for deployment using a digital device



Figure 8: Firefighters training with the NG-SCBA, backed by data collection and analysis

TECHNOLOGICAL ROADMAP AND FUTURE DEVELOPMENTS

e-Staging Integration

The integration of the NG-SCBA system with e-Staging signifies SCDF's next major technological advancement. This resulting platform transforms how resources are managed during emergency operations. In addition to simple resource tracking, it incorporates predictive analytics to optimise resource allocation and deployment.

Advanced Analytics and Decision Support

The e-Staging integration also introduces sophisticated analytics capabilities that improve operational effectiveness. The system analyses patterns in air consumption, movement, and environmental conditions to provide predictive insights that aid in tactical planning. These analytics help commanders anticipate resource needs and identify potential safety concerns before they escalate into critical issues.

Future enhancements to the integrated system will use advanced machine learning algorithms to analyse operational data patterns and suggest optimal tactical approaches. This capability will be particularly valuable in complex scenarios where multiple factors must be considered simultaneously.

Enhanced Digital Ecosystem

SCDF's vision for the future includes further integrating emerging technologies into the NG-SCBA system. Plans encompass the incorporation of thermal imaging displays to provide real-time environmental data and navigation information — including indoor tracking capability — directly within firefighting equipment. This enhancement will improve firefighters' situational awareness while maintaining operational simplicity.

The organisation is also exploring the adoption of automated emergency response recommendations based on real-time data analysis. This system would combine information from multiple sources, including the NG-SCBA telemetry, building management systems, and environmental sensors, to suggest optimal tactical approaches during incidents.

Future developments will focus on improving interoperability with other emergency response agencies. SCDF is working to establish protocols for sharing relevant data across agencies during joint operations to enhance coordination and effectiveness in multi-agency responses. This initiative demonstrates SCDF's commitment to leveraging technology to strengthen emergency response capabilities across the entire public safety sector.

CONCLUSION

SCDF's implementation of the NG-SCBA system demonstrates how innovative thinking and careful planning can transform commercial technology into a comprehensive emergency response solution. The organisation's success in rapidly deploying and adapting this technology, combined with its forward-thinking approach to digital integration, sets a new standard for emergency response capabilities. The ongoing development of e-Staging integration and other digital initiatives ensures that SCDF remains at the forefront of emergency response technology. Through continued innovation and adaptation, SCDF maintains its position as a leader in modern emergency response, ready to meet the evolving challenges of urban firefighting and emergency management.

PHOTOS CREDIT:

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AI-BASED RECOGNITION OF HAZMAT WARNING LABELS

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EDITORIAL PREVIEW

The United States Department of Transportation guidelines require all vehicles transporting dangerous goods, i.e., cargoes containing hazardous materials (HazMat), to affix large, clearly visible hazard warning labels at the front and back of the vehicles. These labels signal the type of hazard each vehicle carries to other road users.

Each label typically conveys information through shape, colour, symbol, and numbers. They are designed to be language-independent so that HazMat emergency responders can quickly identify a cargo's major hazard(s) and be better prepared to mitigate an incident with the appropriate HazMat tools and equipment.

These critical warning labels are applied globally, including in Singapore. Under Singapore's regulatory requirements for the transport of HazMat cargoes, all dangerous goods transporters must display HazMat warning labels or a Transport Emergency Information Panel at the front, sides, and rear of their vehicles. This applies to local- and foreign-registered vehicles transporting cargoes via Tuas Checkpoint.

INTRODUCTION

Border checks and cargo screenings are vital in ensuring that cargoes are transported safely and securely. This is particularly important for Singapore, as a nation with an open economy that thrives on its international trade and commerce.

The rapid growth of international trade, e-commerce, and global supply chain networks has increased demand for shorter delivery times and greater efficiency. However, security cannot be compromised.

Fortunately, technological advancements are paving the way for automated screening solutions. These solutions not only augment border security clearance processes but also reduce clearance duration, creating a more seamless flow of goods across the borders.

A key development in automated detection is Artificial Intelligence (AI)-based object recognition. Border screening is now being enhanced with computer vision algorithms capable of identifying Hazardous Materials (HazMat) warning labels or Transport Emergency Information Panel (TEIP). These algorithms can be trained to accurately detect objects and warning signs.



Figure 1: HazMat labels and TEIP

While training a computer vision algorithm to detect HazMat labels and TEIP may sound straightforward, several challenges may impede the model's performance. For example, labels could be located at any position of the vehicle's rear and sides and may easily fall out of the cameras' viewing range. Moreover, HazMat vehicles are huge — they can be as long as 20 metres and up to 4 metres in height — making it difficult for camera systems to provide full coverage. Additionally, environmental conditions, such as rain and sun glare, may reduce camera visibility. To overcome these challenges, the eventual solution would have to consider camera selection, positioning, and AI algorithm.

CURRENT SCREENING PROCESS FOR HAZMAT VEHICLES AT TUAS CHECKPOINT

Upon arrival at Tuas Checkpoint, all foreign-registered HazMat vehicles undergo several screening steps.

First, the vehicle is scanned by the Immigration and Checkpoints Authority (ICA)'s radiation portal. ICA officers at the immigration clearance counter then check the cargo clearance permit declared by the consignor. Following this, Singapore Civil Defence Force (SCDF) officers at the HazMat inspection counter verify the driver's identity with the HazMat Transport Driver Permit before commencing the HazMat vehicle screening.

During the HazMat vehicle screening, SCDF officers check that the HazMat labels or TEIP are properly displayed on the vehicle and that they tally with the cargoes declared in the cargo clearance permit. The drivers must disembark from their vehicles, produce their permits at SCDF's HazMat inspection counter, and authenticate their biometrics (i.e., fingerprint, iris, and facial recognition) and personal particulars. The SCDF screening process takes between five and eight minutes.

Vehicles that pass SCDF's HazMat vehicle screening will then proceed to ICA's radiographic screening portal to be scanned for illegal immigrants and contrabands before being allowed to leave the checkpoint.

ENVISAGED AI-GENERATED AUTO-SCREENING (BY 2029)

By 2029, it is envisioned that AI-enabled cameras will automatically detect and identify arriving HazMat vehicles at the HazMat inspection lane by reading their HazMat labels or TEIP. Simultaneously, the vehicle will be scanned by Licence Plate Recognition (LPR) cameras to verify that the vehicle is licensed by SCDF. AI-enabled cameras will also cross-check that the displayed HazMat labels or TEIP correspond with the cargo type (e.g., flammable, toxic, etc.) through integration with ICA's pre-arrival cargo declaration app, via its SG Arrival Card e-Service.

At the immigration clearance counter, ICA will then conduct biometric screening of all incoming drivers and passengers, without requiring secondary verification by SCDF. With the automated screening, SCDF will no longer need to check cargo clearance permits or physically inspect vehicles for display of HazMat labels or TEIP. Vehicles will then pass through ICA's radiographic scanner for contraband screening and exit the checkpoint accordingly. Any vehicle that fails either screening will be redirected back to Malaysia by ICA.

METHODOLOGY AND FINDINGS

A trial camera setup was deployed, and datasets were curated to establish a baseline for further assessment of AI modelling capability.

Camera Setup

An axle-counting camera, one of the latest vehicular cameras, was used. The particular model used can capture the front, side, and rear views of the vehicle, and clearly associate the vehicle images with in-built LPR capabilities. Additionally, the camera's deployment footprint is small and requires no overhead setup.

1.6m



Figure 2: An axle-counting camera



Figure 3: Axle-counting camera capturing the front, rear, and side views of vehicles (side image is generated by an automated stitching algorithm within the camera)

As the rear view may not capture the entire vehicle height, a secondary wide-angle rear camera would have to be used. Both cameras' snapshots would also have to be synchronised so the system recognises them as snapshots of the same vehicle.

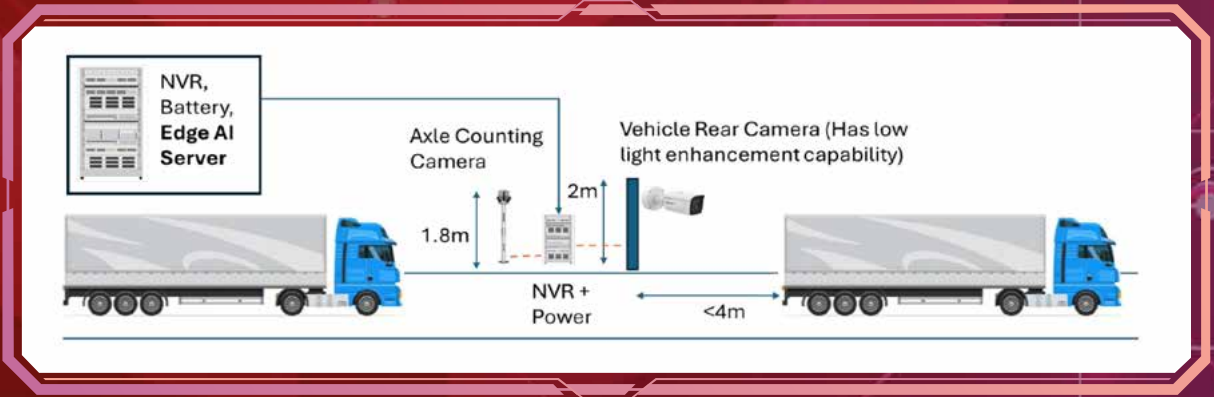


Figure 4: Proposed setup of an axle-counting camera and a vehicle rear camera

Training Dataset Creation

To obtain a baseline model, operational data must be properly secured. From the initial trial, three cameras were deployed on site, capturing over 2,160 hours of video footage. From these videos, snapshots were extracted at one-minute intervals as samples for the study. The snapshots were then put through a vehicle detector tool, which selected over 30,000 images with vehicles. Further manual sorting was performed to remove duplicate and poor-quality images. Approximately 3,800 images containing HazMat labels and TEIP were used to train the AI models for preliminary performance estimation. As some HazMat labels, such as radioactive and explosive, are less common to capture on site, open-source datasets were used to augment the training data. Fortunately, this was easily obtainable given their internationally standardised label designs.

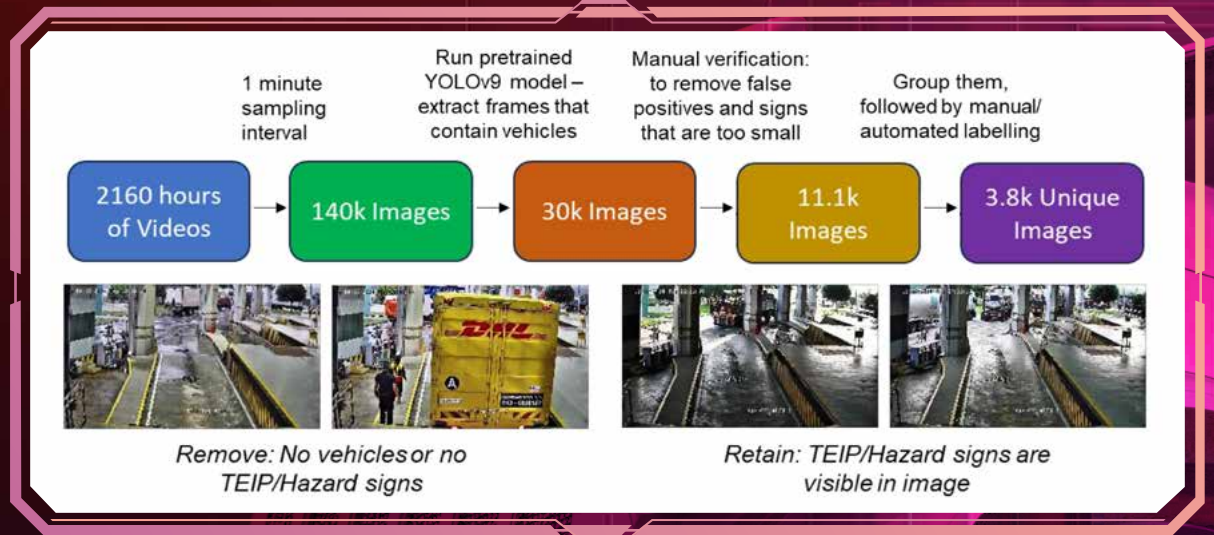


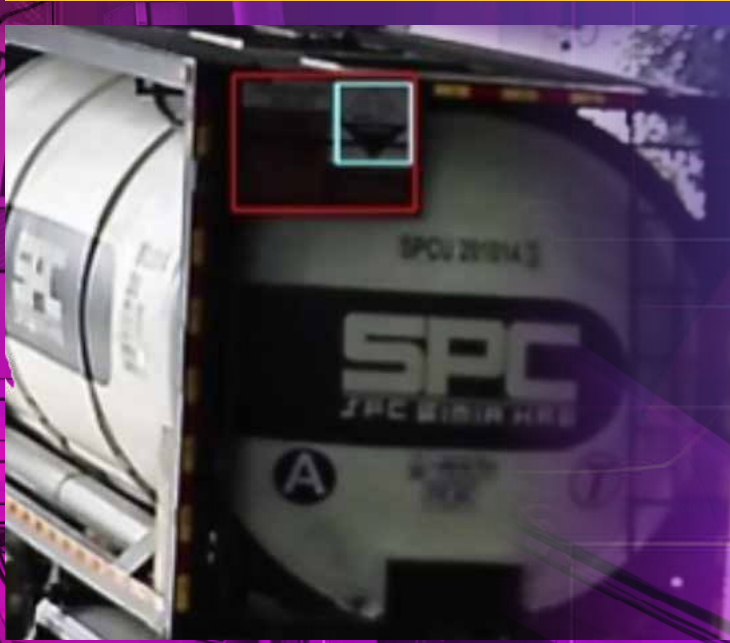
Figure 5: Process of collecting, verifying, and grouping data

AI Model Performance and Results

Two separate models were trained — one for HazMat labels and TEIP detection, another a classification model to identify hazard type. YOLOv9 was used for HazMat labels and TEIP detection, and it achieved a mean average precision of 94.6% on TEIP and 78.8% on HazMat labels. For the hazard classification, EfficientNetv2 was used, and it achieved an accuracy of 93.2%.



Figure 6: AI models detecting HazMat labels and, TEIP, and classifying hazard types



Imaging Quality

One issue identified from our datasets was the under-exposure of TEIPs captured around noon. This occurred because the camera's auto-exposure setting lowered exposure to avoid overexposure from the sun, inadvertently dimming darker areas. One way to mitigate this is to use cameras with wide dynamic range capability.

Figure 7: Under-exposed TEIP located at the top of the vehicle, caused by the camera reducing exposure to avoid overexposure from external surroundings

Operational Challenges

Deploying the axle-counting camera and rear camera will require operational planning. When vehicles moved too close to each other, the rear camera's view became occluded. To mitigate this, a minimum separation distance of 4 metres will be required when approaching the cameras. This can be enforced by demarcating a yellow box at the checkpoint.

Variations In HazMat Labels

An additional challenge is the variation in HazMat labels. As the HazMat labels were manufactured in Malaysia, the patterns and variations may differ from international standards used to train the model. The model may perform poorly if a different design standard is used. The flammable gas and flammable liquid labels, for example, can vary widely in design and affect the model's accuracy.

HAZMAT LABELS	VARIATIONS
Flammable Gas	
Flammable Liquid	

Figure 8: Variations In HazMat labels

CONCLUSION

AI-based object detection provides capabilities to overcome problems previously unsolvable by rule-based algorithms and opens the door to new detection possibilities. Emergency responders and law enforcers can now leverage AI technology for active monitoring and enforcement at inspection counters, enabling immediate action against regulatory non-compliances.

This article demonstrates how AI can be used to localise, classify, and segment HazMat labels and TEIP on vehicles for auto-screening. From the AI modelling analyses, experimental results show that such technology has the potential to reliably identify arriving HazMat vehicles at the checkpoint.

In future works, it may be worth looking into and developing the integration of optical or specific character recognition within HazMat labels. The ability to detect entire labels independent of the labels' background colours or symbols would help improve detection accuracy.

Automated HazMat vehicle identification and cargo verification enhance border safety and security by optimising manual resources and streamlining monitoring processes. By automating data collection and procedures, incidents involving falsified or erroneous cargo declarations may be addressed holistically. This translates into enhanced HazMat vehicle screening efficiency at the checkpoint borders.

FIREFIGHTING HOSE HANDLING

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EDITORIAL PREVIEW

Fighting fires is a marathon, not a sprint. Preserving energy is a fundamental principle of firefighting. With a full self-contained breathing apparatus set, pushing into the fire and countering the pressure and nozzle reaction is part and parcel of firefighting. However, working against these forces can quickly lead to fatigue if done incorrectly. Firefighters tasked with operating a hose line not only have to be smart about the way they suppress fires but also manage how they handle the hose. A wide array of nozzle and hose handling techniques is crucial to keeping fatigue at bay.

Firefighting hoses and nozzles are indispensable tools for frontliners, yet the way they are handled has significant implications for ergonomics, safety, and long-term health. Currently, the Singapore Civil Defence Force (SCDF) relies on pistol grip nozzles, with training focused on pistol grip postures (PGP). While effective in some contexts, PGP can be fatiguing and ergonomically restrictive during prolonged operations. Internationally, alternative non-pistol grip postures (NPGP) have demonstrated advantages in reducing strain, enhancing stability, and lowering ergonomic risk. This article explores a comparative ergonomic assessment of PGP and NPGP techniques, highlighting the value of integrating NPGP into SCDF's training curriculum.

INTRODUCTION

The firefighting hose is a widely used firefighting equipment that delivers water from a pressurised source (for example, a fire hydrant or water tank) to a fire. A nozzle is usually equipped at the end of the hose to break the water stream into small droplets, which are then sprayed at high speed. Fine water droplets extinguish fires by absorbing heat during vaporisation, cooling the fire below its ignition temperature.

Commercially, most nozzles are available in two versions: with a pistol grip (Figure 1A) and without a pistol grip (Figure 1B). Currently, the Singapore Civil Defence Force (SCDF) utilises nozzles with a pistol grip, for example, Style 366E (Figure 1C) and Style 390 (Figure 1D) from Protek Manufacturing Corp. Accordingly, the training curriculum is limited to pistol grip posture (PGP). In this posture, one hand holds the bale handle, while the other holds the pistol grip, with the hose under the armpit (Figure 2A).



*Figure 1: Nozzles used in firefighting –
(A) with pistol grip, (B) without pistol grip, (C) Style 366E, and (D) Style 390*

PGP has its own merits. It is easy to learn and has multiple pinch points. However, it is not the optimal method for some use cases. For example, it is restricted by the shoulder angle and can become very tiring during prolonged operations. Indeed, many other proven non-pistol grip postures (NPGPs) have been implemented internationally. Examples include the Tanaka grip posture (TGP), the clamp posture (TCP), and the under-arm clamp posture (UACP). A common feature of these postures is that they do not require firefighters to hold the pistol grip, even when using a pistol grip nozzle. The nozzle is operated away from the face and body.

TGP is an ideal posture for both offensive and defensive operations, especially those requiring multiple movements. The firefighter stands with feet apart, with one hand holding the nozzle and the other holding the hose (Figure 2B). The bale is adjusted one hand's length away from the body for quick shut-off and easy access.

TCP is suited for prolonged defensive operations with minimal movements. With the hose secured under and between the quads, the firefighter sits on the hose to ground the nozzle reaction (Figure 2C). Both hands remain on the hose and nozzle, not the bale, to avoid unnecessary shut-off.

UACP is the default posture suitable for multiple operations. The firefighter is supported by one knee on the ground and by sitting back on the leg (Figure 2D). Similar to PGP, the hose is held under the armpit, but the back hand holds the hose instead of the pistol grip.

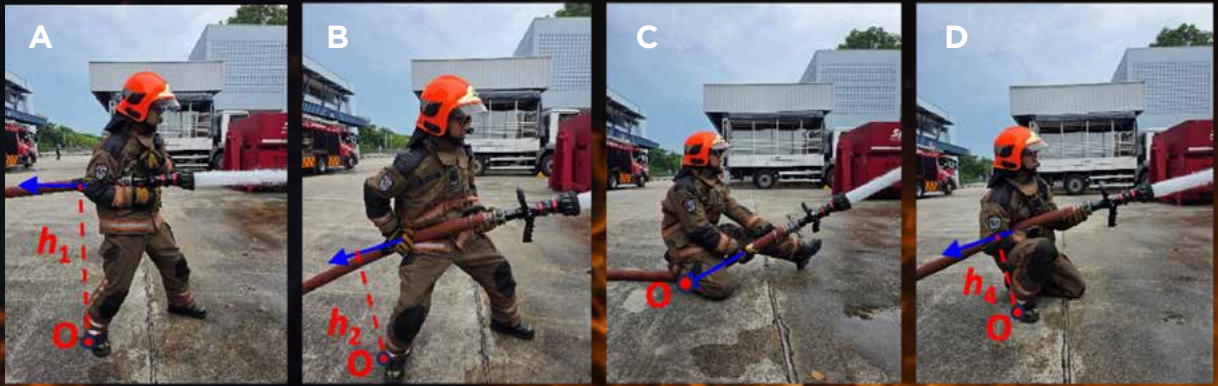


Figure 2: Hose handling postures — (A) pistol grip, (B) Tanaka grip, (C) the clamp, (D) under-arm clamp. The blue arrows represent the nozzle reaction, the dotted red lines and h represent the moment arm of the nozzle reaction, and O denotes the axis of rotation.

In this study, we conduct a comparative analysis from an ergonomic perspective. We compare the merits and limitations of the different handling techniques, followed by a discussion on the possible inclusion of the NPGPs into the training syllabus. The analysis can be categorised into the following four aspects: force, range of motion, stability, and ergonomic risk.

FORCE ANALYSIS: NOZZLE REACTION AND GRAVITY

External forces exert a strain on the human body and can cause damage to body parts or tissues. The main forces exerted by the hose and nozzle on the firefighter's body are nozzle reaction and gravity. As shown in Figure 3A, the nozzle reaction points in the opposite direction of the water jet, while gravity always points downwards.

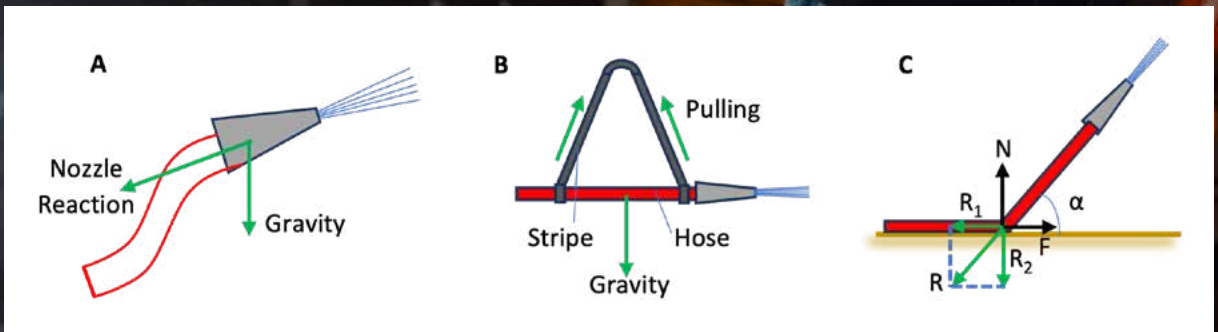


Figure 3: Schematic drawing of (A) forces from the hose and nozzle, (B) pulling force from the stripe, and (C) nozzle reaction for TCP

Calculation of Nozzle Reaction

Nozzle reaction refers to the amount of force directed back to the firefighter due to the volume and speed of water leaving the nozzle. This force may increase the firefighter's air consumption rate, fatigue, and risk of injury. It has been reported that the nozzle reaction causes an average of 13,795 firefighting injuries every year [1].

For a fixed hose and nozzle, the nozzle reaction R can be calculated using the following equation [2]:

$$R = (2 \rho \, Q^2 p_1 + \rho^2 \, Q^4 / A_1^2)^{0.5}$$

where Q is the flow rate (m^3/s), ρ is water density (kg/m^3), p_1 is the pressure of the hose, and A_1 is the corresponding cross-sectional area of water in the hose.

Measurement of Gravity

A spring scale was used to measure the total weight of the hose, the nozzle, and the water inside. The length of the hose was found to be 1.2 m from the ground to the tip of the nozzle. With one hose end lying on the ground, the total weight was measured to be 10.12 kg for both the 38 mm hose (corresponding to Style 366E nozzle) and the 64 mm hose (corresponding to Style 390 nozzle).

The nozzle reaction and gravity for the two nozzles at different flow rates are summarised in Table 1.

Table 1: Calculated nozzle reaction and gravity for the two nozzles					
Nozzle	Q (m^3/s)	Reaction (N)	Weight (kg)	Gravity (N)	Reaction/Gravity
Style 366E	115	71.8	10.12	99.2	0.7
	230	144.0	10.12	99.2	1.5
	360	226.7	10.12	99.2	2.3
	475	301.3	10.12	99.2	3.0
	600	375.4	10.12	99.2	3.8
Style 390	750	470.1	10.12	99.2	4.7
	900	565.3	10.12	99.2	5.7
	1050	661.3	10.12	99.2	6.7
	1200	758.0	10.12	99.2	7.6

From the table, it can be seen that nozzle reaction typically exceeds gravity, especially at high flow rates. In practice, the gravity of the hose can be offset by the pulling forces from the shoulder stripe (Figure 3B). Therefore, the main challenge is countering nozzle reaction.

Nozzle Reaction for Different Handling Techniques

For PGP, TGP, and UACP, the hose and nozzle are only in contact with the officer's body. Thus, the reaction force will be countered solely by the officers, though different muscle groups may be activated for different postures. For example, in TGP, the back hand can be placed near the hip so the hipbone and pelvis may also help counter the nozzle reaction.

This is different for TCP, where the hose is also in contact with the ground. As shown in Figure 3C, the reaction force R on the ground can be decomposed into a horizontal component R_1 and a vertical component R_2 . The ground supporting force N balances R_2 , while R_1 pushes the firefighter backwards. This backward force is countered by the friction F between the firefighter's knee and the ground. Therefore, the body does not need to counter the reaction force directly, reducing fatigue. However, the lower the elevation angle α , the higher the friction needed to keep the officer from moving backwards. This may be challenging when the floor or the pants are wet.

RANGE OF MOTION ANALYSIS: DIRECTIONAL CONTROL OF NOZZLE

A major complaint about PGP is that when the nozzle is held tightly against the body, the posture limits the range of motion and area that can be covered by the water jet. This can be explained by the schematic drawings in Figure 4.



Figure 4: Schematic drawings of the directional control of the nozzle for PGP and NPGP

In PGP, both the hose and nozzle are positioned close to the body. To point the nozzle in a new direction, the firefighter must turn their entire body by nearly the same angle β . Simply twisting the upper body is not practical as it would result in an awkward and unsustainable position during extended operation. If an operation requires rotating the nozzle to control the fire in a large area, the frequent turning or twisting of the body would quickly exhaust the nozzle operator before the fire is fully extinguished.

In contrast, the three NPGPs position the nozzle at one arm's length in front of the body, allowing the hose to bend near the body. Firefighters can easily move and change the nozzle's direction with minimal or no need to turn the body. As a result, the nozzle operator can manoeuvre the nozzle more freely and sweep the water jet in a circular motion. Comparatively, holding onto a pistol grip requires a lot more arm and body work to achieve the same effect.

The NPGPs allow firefighters to cover a larger area with water and enable more precise nozzle control for targeted fire suppression. It is like comparing the difference between firing a pistol from the hip and using a long rifle stabilised against the shoulder to consistently land accurate shots [3].

STABILITY ANALYSIS: TORQUE ON THE HUMAN BODY

Maintaining the necessary stability during firefighting is essential. If the nozzle reaction cannot be countered, the firefighter may be pushed backwards or fall over. This risk is heightened when opening or closing the nozzle, or when adjusting the flow rate. In such situations, the sudden increase or decrease in nozzle reaction can cause the nozzle operator to lose balance and potentially sustain an injury.

Whether an object is rotationally stable depends on the torque on it. Torque is defined as the product of the moment arm and the tangential force. As shown in Figure 5, the gravity G , acting at the centre of gravity CG , helps the body to maintain an upright stance. The force R at the shoulder pushes the body to pivot around the back foot O and fall.

- If $R \times h < G \times d$, the person will remain stable;
- If $R \times h > G \times d$, the person will topple over in an anticlockwise direction.

To enhance stability, knees can be bent to lower the height h . Alternatively, the stance can be widened to increase the distance d .



Figure 5: Schematic drawing of the stability of a human body

This principle can be applied to compare the stability of the different postures mentioned above. For a fair comparison, we assume that the nozzle reaction R , the elevation angle α , and the distance between the two feet are identical across all postures. Therefore, torque for gravity will remain the same, and the stability of the body depends solely on the moment arm h . A higher value of h results in a larger torque ($R \times h$) of the nozzle reaction, corresponding to decreased rotational stability.

The moment arm for various postures is shown in Figure 1.

- PGP: The hose is held under the armpit, corresponding to a moment arm of h_1 .
- TGP: The back hand is placed at the pelvis, closer to the axis of rotation O , so $h_2 < h_1$.
- TCP: The nozzle reaction acts through the knee O , so $h_3 = 0$. This means that the reaction does not affect stability regardless of how large the reaction force is.
- UACP: Since the officer needs to squat down to operate the nozzle, the hose is much closer to the back foot, therefore $h_4 \ll h_1$.

In summary, the moment arm of nozzle reaction in all three NPGPs is lower than that in the PGP. Correspondingly, the reduced torque might lead to an increase in the rotational stability of the officer when handling the hose and nozzle during firefighting operations.

STABILITY EXPERIMENT USING EXCEL'S STRIVE SYSTEM

To further test the stability of the various firefighting postures, we conducted an experiment using the Strength Conditioning and Rehabilitation in a Virtual Environment (STRiVE) in the Civil Defence Academy's Emergency Responders Fitness Conditioning and Enhancement Lab (EXCEL). Using STRiVE's centre of pressure (CoP) tracking function, we assessed the extent of recoil experienced by firefighters under nozzle pressure. To simulate the reaction force experienced when switching the nozzle on, we had one firefighter suddenly tug back on the hose while another firefighter holding the nozzle was positioned in the various postures. We hypothesised that the greater the movement of the firefighter's CoP upon experiencing the backward force, the more unstable the posture is.

We tested each posture — PGP, TGP, TCP, and UACP (Figure 6) — with and without the self-contained breathing apparatus (SCBA). For each combination of posture and attire, we performed three repetitions to ensure accuracy. The results are shown in Table 2. The CoP of the firefighter is indicated by the blue dot, with a blue trail showing its movement during the test.



Figure 6: Overview of the experiment setup in STRiVE

Table 2: Compilation of the results from the STRiVE experiment

Firefighting Posture	Centre of Pressure (without SCBA)	Centre of Pressure (with SCBA)	Observations
Pistol Grip Posture (PGP)	 EMG1: 0.00 EMG2: 0.00 Center of Pressure CoPx: -0.006 CoPz: 0.221 FP1: 605N FP2: 411N	 EMG1: 0.00 EMG2: 0.00 Center of Pressure CoPx: -0.045 CoPz: 0.143 FP1: 668N FP2: 490N	Upon experiencing the backward force, the firefighter's weight shifts backwards significantly, with some lateral movement as well. Lateral movement suggests instability as firefighters may fall sideways.
Tanaka Grip Posture (TGP)	 EMG1: 0.00 EMG2: 0.00 Center of Pressure CoPx: -0.004 CoPz: 0.530 FP1: 553N FP2: 483N	 EMG1: 0.00 EMG2: 0.00 Center of Pressure CoPx: 0.023 CoPz: 0.237 FP1: 613N FP2: 580N	There is a comparable extent of recoil backwards to PGP. Notably, there is no lateral movement, unlike PGP.
The Clamp Posture (TCP)	 EMG1: 0.00 EMG2: 0.00 Center of Pressure CoPx: 0.091 CoPz: 0.042 FP1: 322N FP2: 743N	 EMG1: 0.00 EMG2: 0.00 Center of Pressure CoPx: 0.065 CoPz: 0.347 FP1: 161N FP2: 1048N	There is little to no movement upon experiencing the backward force. It can be reasoned that the TCP provides a stable posture.
Underarm Clamp Posture (UACP)	 EMG1: 0.00 EMG2: 0.00 Center of Pressure CoPx: 0.052 CoPz: -0.173 FP1: 642N FP2: 330N	 EMG1: 0.00 EMG2: 0.00 Center of Pressure CoPx: -0.019 CoPz: 0.056 FP1: 828N FP2: 377N	The backward recoil is less than PGP and TGP. However, there is notable lateral movement.

Due to the limitations of the experiment design, we were unable to derive a quantitative analysis of the posture's stability. Nevertheless, the results show a qualitative picture of how the various postures fare in terms of their stability. To summarise, TCP is the most stable of the four postures based on the experimental trial within STRIVE. This agrees with the findings from the torque-based stability analysis in the previous section.

ERGONOMIC RISK ANALYSIS: RULA

The Rapid Upper Limb Assessment (RULA) is an ergonomic tool developed to evaluate the exposure of individual workers to ergonomic risk factors associated with upper extremity musculoskeletal disorders (MSD). RULA considers the biomechanical and postural demands of tasks on the neck, trunk, and upper extremities. It provides a simple scoring method with an action-level output that requires minimal time, effort, and equipment [4].

To conduct a RULA analysis, evaluators must first identify the most difficult postures and work tasks. This is followed by a 15-step assessment approach, which includes (1) an analysis of the arms and wrists; and (2) an analysis of the neck, trunk, and legs. Scores are assigned based on the location of the body parts, muscles used, and applied force or load. More details of the analysis can be found in [5].

The RULA scores for both PGP and NPGP for a right-handed firefighter are shown in Table 3. Results for NPGP represent the average of the three NPGP (TGP, TCP, and UACP), where the centre of gravity is better distributed and the force is not solely reliant on the upper limb.

Table 3: RULA scores for hose handling techniques	
Posture	RULA Score
PGP (right side)	7
PGP (left side)	7
NPGP (right side)	3
NPGP (left side)	3

A RULA score of 7 corresponds to a very high level of MSD risk, with a need to “investigate and implement changes”. In contrast, a RULA score of 3 indicates low MSD risk, where “further investigation, change may be needed” [6]. Therefore, NPGP may pose a lower ergonomic risk to nozzle operators than PGP does.

Table 4 summarises the ergonomic analysis made on the two types of hose handling techniques.

Table 4: Comparison of the ergonomic analysis results on PGP and NPGP		
Ergonomic Analysis	PGP	NPGP
Force	Nozzle reaction is fully countered by the body.	In TCP, nozzle reaction is partially countered by the ground, and less gravity is exerted when the pistol grip is not installed.
Range of Motion	Nozzle movement is restricted to the shoulder angle of the nozzle operator. Frequent body turning or twisting is needed to cover a large area.	Nozzle can be moved easily to cover a large area with minimal or no turning of the body.
Stability	Rigid, counteractive posture, best for defensive operations	Improved rotational stability, best for offensive, defensive, and prolonged operations
Ergonomic Risk	RULA Score = 7, very high MSD risk	RULA Score = 3, low MSD risk

RECOMMENDATION

As mentioned, firefighters can use the NPGP techniques on nozzles with a pistol grip. Therefore, these techniques can be applied to existing SCDF nozzles and introduced at no additional cost. Ergonomically, NPGP improves posture and stability. Moreover, it enhances firefighting effectiveness and reduces long-term health risks.

Nevertheless, it has been reported that some firefighters overseas found benefits in removing the pistol grip: (1) Pistol grips reinforce bad habits like grasping the pistol grip tightly so that the nozzle is too close to the body; (2) Firefighters tend to drag the hose by a pistol grip, which poses the risk of accidentally knocking the bale open and having it ripped from their hands, creating a safety hazard [3]. Additionally, removing the pistol grip can reduce the weight of the current nozzles.

PGP is an easy-to-learn technique suitable for specific scenarios, such as defensive firefighting with limited movement. Therefore, the objective of this study is not to replace the PGP. Rather, it aims to introduce NPGP techniques into the training syllabus to enhance firefighters' safety and skill sets.

An important motivation for this study is to address the unsafe hose-handling practices observed in firefighting operations. Without training in other techniques, frontliners may adopt makeshift postures in scenarios where PGP is unsuitable. For example, firefighters may sit in a chair while hoisting the hose during prolonged operations. This can be very dangerous as sudden changes in nozzle reaction may cause loss of stability. In such cases, TCP offers a safer and more effective alternative, reducing fatigue while retaining rotational stability.

CONCLUSION AND FUTURE WORK

This study demonstrates that NPGP techniques provide tangible ergonomic benefits over the current PGP in specific operational contexts. By improving posture, stability, and reducing ergonomic risk, the NPGP techniques can significantly enhance firefighter safety, reduce fatigue, and lower the long-term health impact of hose and nozzle handling. Thus, NPGP presents a highly feasible and impactful addition to the current training syllabus. Rather than replacing PGP, the proposed approach advocates for a complementary integration of NPGP that targets operational scenarios where it offers greater ergonomic advantages.

Future work will involve the structured incorporation of NPGP techniques into the formal SCDF training curriculum. This includes the development of instructional materials, practical drills, and assessment criteria. Additionally, further studies could evaluate the long-term effects of NPGP on physical strain and injury rates among firefighters, as well as its use in more complex firefighting scenarios such as confined spaces or elevated platforms. Continuous feedback from frontliners will be essential in refining the techniques and ensuring their practicality, relevance, and adoption across diverse firefighting environments.

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ONLINE RESILIENCE TRAINING INTERVENTION FOR PARAMEDICS: BASELINE FINDINGS

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EDITORIAL PREVIEW

Paramedics play a crucial role in emergency medical services, often serving as the first responders to critical and life-threatening situations. Frontline paramedics are regularly exposed to high-stress environments, which increases their susceptibility to stress-related difficulties such as burnout. This study examined the impact of the COVID-19 pandemic on the mental health and overall well-being of 62 paramedics from the Singapore Civil Defence Force.

Participants were recruited during the COVID-19 pandemic and post-pandemic periods. As the study was ongoing, this article focused on baseline findings from a randomised clinical trial evaluating an online resilience training programme for frontline paramedics. Results indicated that a substantial number of participants scored above clinical cut-offs for depression, post-traumatic stress, anxiety, psychological distress, and burnout. The majority of participants reported either medium or high levels of social support and high levels of psychological resilience. However, rates of depression, anxiety, post-traumatic stress, and burnout were not significantly different between the pandemic and post-pandemic groups. Study findings and recommendations are discussed.

BACKGROUND

Paramedics play a crucial role in Emergency Medical Services (EMS), often serving as the first responders to critical and life-threatening situations (Folwell & Kauer, 2018). Frontline paramedics are regularly exposed to high-stress working conditions, which increase their susceptibility to stress-related difficulties (Regehr & Millar, 2007).

For instance, paramedics are at greater risk of experiencing psychological distress. A study on paramedics and ambulance volunteers from Australia and New Zealand showed that participants exposed to at least one adverse event while working reported higher psychological distress scores than those who were not (Mackinnon et al., 2020). A survey looking at EMS personnel in the United States also found that more than 85% experienced chronic stress (Barber et al., 2015).

Paramedics' health-related quality of life issues, such as physical health, sleep, and chronic pain, can also be significantly affected by the stressors faced (Sterud et al., 2006). Tasks such as stretcher handling and patient extraction have been reported as the most physically demanding, often leading to musculoskeletal injuries, particularly sprains, strains, and back injuries (Marsh et al., 2025). A systematic review found that paramedics commonly experienced both poor-quality sleep and excessive daytime sleepiness (Kendrick et al., 2025). Previous literature showed that baseline insomnia predicted increased depression symptoms at the six-month follow-up in recruit paramedics, highlighting sleep disturbances as a potential risk factor for the development of depression in paramedics. Depression is characterised by persistent sadness, loss of interest, and fatigue. Paramedics experiencing these symptoms may struggle with daily activities and maintaining a positive outlook (Sterud et al., 2006).

Paramedics may also experience heightened levels of anxiety due to the unpredictability and high-stakes nature of their work. This can manifest as excessive worry, restlessness, and difficulty concentrating. A Canadian study of emergency response and correctional workers found that the anxiety rate among paramedics was as high as 22% (Carleton et al., 2018). Another potential stress-related difficulty is post-traumatic stress, which may include symptoms such as flashbacks, nightmares, severe anxiety, and uncontrollable thoughts about the traumatic events (Alexander & Klein, 2001). A meta-analysis of work-related post-traumatic stress disorder (PTSD) in paramedics found that paramedics had a considerably higher pooled prevalence of PTSD than the unexposed general population and populations affected by human-made disasters (Hoell et al., 2023). Additionally, a systematic review of 27 international studies on ambulance personnel found estimated prevalence rates of 11% for post-traumatic stress, 15% for depression, 15% for anxiety, and 27% for general psychological distress (Petrie et al., 2018).

Paramedics may also be at higher risk of burnout, which is a state of emotional, physical, and mental exhaustion caused by prolonged stress. Paramedics may feel overwhelmed, emotionally drained, and unable to meet constant demands (Leppin et al., 2014). In a systematic review on the prevalence and predictors of burnout in paramedic populations, the prevalence of burnout in paramedics ranged from 16% to 56% (Reardon et al., 2020). High levels of burnout and stress can negatively impact work engagement, reducing paramedics' enthusiasm and commitment to their job. A systematic review on work engagement among EMS personnel showed that emotional exhaustion and depersonalisation, both dimensions of burnout, were negative predictors of job satisfaction and work engagement (Thielmann et al., 2023).

In general, prolonged stress reactions among paramedics can adversely affect the daily operations and, more broadly, the nation's preparedness and collective response to public health threats such as COVID-19. Strong resilience and social support have been found to mitigate these effects. In a study on Australian paramedics, resilience showed a significant correlation with general health and well-being (Gayton & Lovell, 2012). Meanwhile, perceived lack of social support predicted depression and post-traumatic stress symptoms in another study (Reti et al., 2021).

These stress reactions may worsen during public health emergencies, such as the COVID-19 pandemic. For example, more than 30% of a sample of paramedics from Saudi Arabia experienced severe psychological distress during the first wave of COVID-19 (Alghamdi et al., 2023). Another study of 300 paramedics in Poland found that performing duties during COVID-19 may have

influenced their psychological condition, with over 80% of them experiencing moderate to very high levels of stress (Spychała et al., 2023). Given the demanding nature of paramedics' work and susceptibility to chronic stress and poor work outcomes, especially during public health emergencies, it is essential to implement practices and programmes to support and improve their workplace resilience.

ONLINE RESILIENCE TRAINING INTERVENTION FOR PARAMEDICS

Resilience training equips individuals with skills to cope with stress and adversity, thus enhancing their ability to bounce back from challenging situations. These programmes often include modules on stress management, cognitive-behavioural strategies, mindfulness, and emotional regulation. The online programme provides paramedics the flexibility to train at their convenience and pace, making it easier to fit into their demanding schedules (Joyce et al., 2018). A meta-analysis suggested that resilience training delivered over the Internet with a flexible programme schedule was more effective than its counterparts (Ang et al., 2022).

Research has shown that online resilience training can significantly improve mental health, enhance coping mechanisms, and boost work engagement by fostering a sense of purpose and accomplishment. A study by Wild et al. (2016) found that participants who completed an online resilience training programme reported reduced levels of stress, anxiety, and depression. Another study by Leppin et al. (2014) also found that such training enhanced psychological well-being and job satisfaction among healthcare professionals.

AIM OF STUDY

Singapore Civil Defence Force (SCDF), the primary provider of EMS and fire services in Singapore, consistently requires a high level of response from its frontline paramedics. In 2024, Singapore recorded 245,279 EMS calls, an increase of 28% from 2019, which recorded 191,468 EMS calls before COVID-19 (SCDF, n.d.). To better support our paramedics in managing such high work demands, it is essential to provide timely support to build resilience and prevent negative stress-related outcomes.

To date, few evidence-based interventions have successfully improved the resilience of emergency responders (Wild et al., 2020). One such intervention, Oxford-Online — an internet-delivered cognitive resilience training developed by Oxford University and designed specifically for paramedics — may be particularly suited to support Singapore's frontline paramedics during prolonged public health emergencies. Consistent with the cognitive model of psychological resilience (Parsons et al., 2016), Oxford-Online focuses on enhancing cognitive processes such as reappraisal and concrete information processing, promoting a more adaptive response in the face of adversity. Potential benefits include internet-based training to reduce face-to-face contact and risk of viral transmission; increased privacy, convenience, and anonymity for participants; and equipping paramedics with cognitive skills shown to reduce the impact of potentially traumatic events (Wild et al., 2018). The six-week internet-delivered resilience training may equip paramedics with helpful coping strategies to reduce the impact of working under epidemic conditions, preventing subsequent psychological distress and more serious problems like depression and PTSD.

This study aims to evaluate the effectiveness of this online resilience training in a sample of SCDF paramedics who worked during the COVID-19 pandemic. As data collection is ongoing for participants from the last wave of recruitment, this article will focus on the baseline preliminary findings of the study:

1. How do the baseline stress and resilience measures of SCDF paramedics compare with clinical cut-offs?
2. Do paramedics recruited during the COVID-19 pandemic period differ in their stress and resilience levels from those recruited during the post-pandemic period?

METHODOLOGY

The sample consisted of 62 frontline paramedics from SCDF. Figure 1 outlines the study's procedure, including recruitment and data collection.

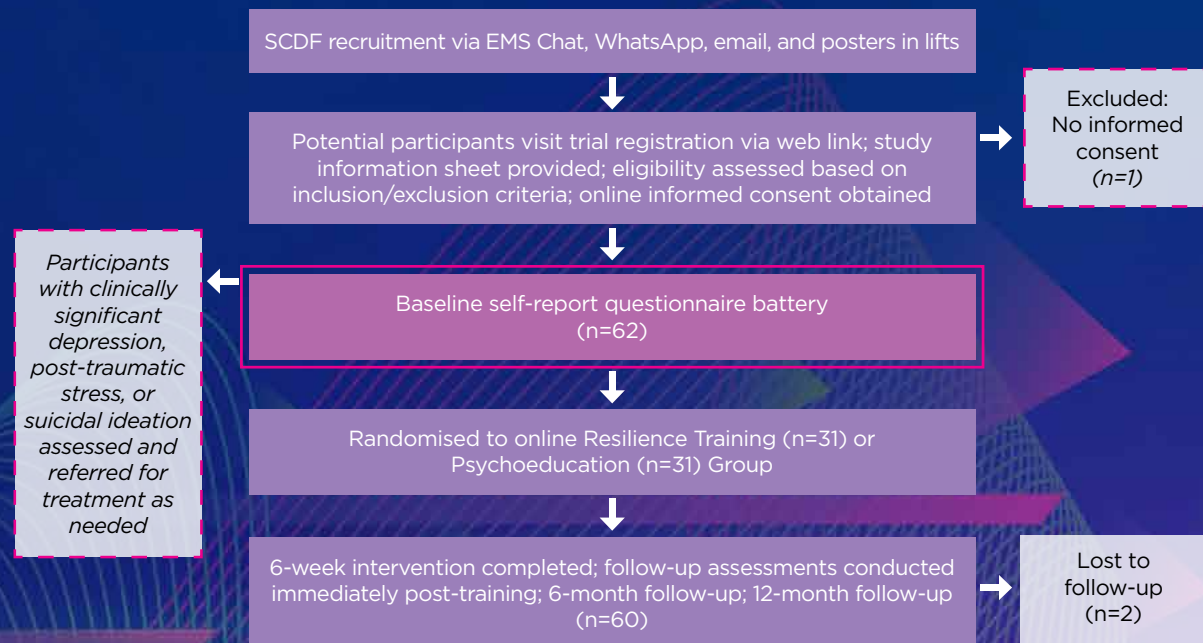


Figure 1: Study procedures flow chart

Recruitment took place in several ways, including presentations at quarterly online and in-person staff meetings (EMS Chat) (Figure 2), posters in lifts at each SCDF division (Figure 3), as well as email and WhatsApp messages disseminated via SCDF champions.



Figure 2: Study recruitment via presentation at SCDF staff meetings

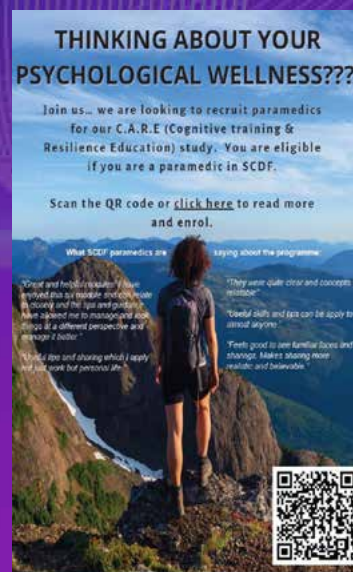


Figure 3: Recruitment poster

Participants were enrolled during the COVID-19 pandemic (Transition Phase, 22 November 2021 to 25 April 2022) and the post-pandemic period (Resilient Nation/Acute/Endemic Phase, 26 April 2022 to 6 April 2024) (Figure 4). The demographics of the sample can be found in Table 1.

Table 1: Demographics of participants (N = 62)

		n=62
Gender, n (%)	Female	24 (38.7)
	Male	38 (61.3)
Age, mean (SD)		30.16 (5.57)
Race, n (%)	Chinese	25 (40.3)
	Indian	9 (14.5)
	Malay	21 (33.9)
	Other	7 (11.3)
Marital Status, n (%)	Divorced/separated	2 (3.2)
	Married	30 (48.4)
	Single/never married	28 (45.2)
	Other	2 (3.2)
SCDF Division, n (%)	1 st	20 (32.3)
	2 nd	15 (24.2)
	3 rd	13 (21.0)
	4 th	14 (22.6)

TIMELINE OF COVID-19 IN SINGAPORE



Figure 4: Recruitment of participants for the study, whereby the orange box indicates the Transition Phase and the blue box the Endemic Phase

Resilience Programmes

Participants were randomly assigned to either the experimental (N = 31) or control group (N = 31).

For the experimental group, participants completed six sessions of Oxford-Online, which targeted cognitive predictors of depression and PTSD (Wild et al., 2016). The core information was delivered in six weekly 20-minute modules (Figure 5). These modules included whiteboard videos explaining concepts, audio files for practising concrete thinking, video testimonies, and footage of paramedics on call for use in experiential exercises. A trained online wellness coach (research assistant) provided individual email feedback on participants' responses for hands-on exercises and quizzes, and sent brief automated SMS reminders of key points and practice exercises. The content was also adapted for local use by including vignettes and narratives from Singaporean paramedics to meet local needs.

For the control group, participants went through a six-session package of general psychoeducational materials (Mind-Online), where participants read information and advice about stress, depression, post-traumatic stress, sleep problems, anger, and mindfulness (Figure 6). Participants in the Mind-Online group received the same frequency, type, and duration of remote support as those in the Oxford-Online group.



Figure 5: Oxford-Online resilience programme for the experimental group

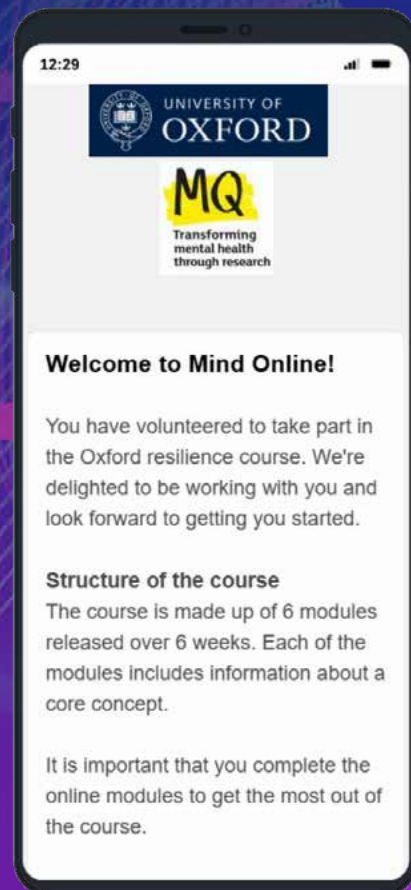


Figure 6: Mind-Online package of psychoeducational materials with resource links for the control group

Measures

Nine measures, detailed in Table 2, were collected at four time points:

1. At the start of the resilience programme (baseline survey in week 1)
2. Upon completion of the resilience programme (week 6)
3. Six months after the programme
4. One year after the programme

Baseline measures of these scales were compared with the mean scores and the percentage of participants scoring above clinical cut-offs.

As a token of appreciation, participants were given \$30 cash following the completion of each survey after the baseline survey (i.e., up to \$90).

Table 2: Study questionnaires

Construct	Measure
Depression	Patient Health Questionnaire 9 (PHQ-9) (Kroenke et al, 2001)
Post-traumatic Stress	Post-traumatic Stress Disorder Checklist for DSM-5 (PCL-5) (Blevins et al., 2015)
Anxiety	Generalised Anxiety Disorder Scale (GAD-7) (Löwe et al., 2008)
Burnout	Physician Work-Life Study (Dolan et al., 2015)
Psychological Distress	General Health Questionnaire (GHQ) (Goldberg & Williams, 1988)
Social Support	Multidimensional Scale of Perceived Social Support (MSPSS) (Zimet et al., 1988)
Psychological Resilience	Connor-Davidson Resilience Scale (CD-RISC) (Connor & Davidson, 2003)
Work Engagement	Utrecht Work Engagement Scale (UWES) (Schaufeli et al, 2017)
Health-Related Quality of Life	EuroQoL 5 Dimensions Questionnaire (EQ-5D5L) (Herdman et al., 2011)

RESULTS

Baseline data indicated that a substantial number of participants scored above clinical cut-offs for depression (n=15, 24.2%), post-traumatic stress (n=13, 21.0%), anxiety (n=9, 14.5%), psychological distress (n=34, 54.8%), and burnout (n=34, 54.8%). The majority of participants reported either medium (n=26, 41.9%) or high levels of social support (n=31, 50.0%) and high levels of psychological resilience (n=36, 58.1%).

Rates of depression, anxiety, post-traumatic stress, and burnout were not significantly different between the pandemic and post-pandemic groups (Figure 7).

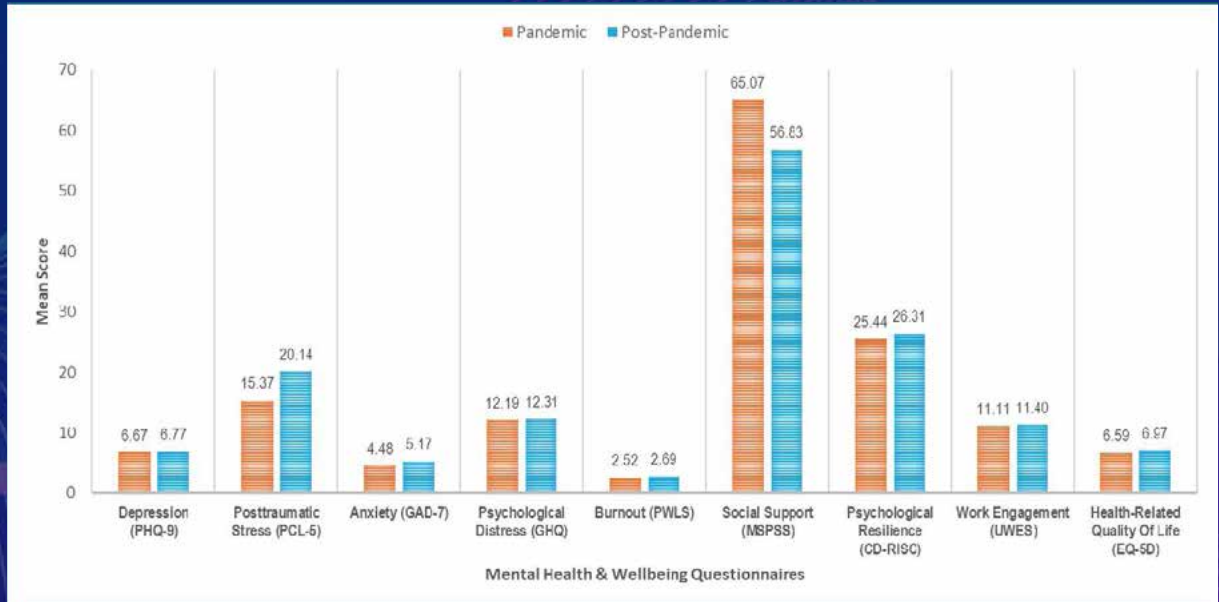


Figure 7: Results for pandemic vs post-pandemic groups

DISCUSSION AND CONCLUSION

Similar to results from other countries, baseline stress-related difficulties and job burnout were frequently reported by SCDF paramedics working on the frontlines during both the acute phase of the COVID-19 pandemic and the post-pandemic period. While many studies have provided evidence of paramedics experiencing heightened stress and burnout during the pandemic, no studies, to our knowledge, have investigated the differences in stress and resilience levels of paramedics during the pandemic and the post-pandemic period. Our study findings suggest that the COVID-19 pandemic may have carry-over effects on paramedics' well-being, even after the end of the pandemic. This could be because the medical calls experienced by SCDF paramedics continued to remain high, and paramedics faced a similar level of workload and stressors after the pandemic. While our study started out with the aim to support paramedics during the COVID-19 pandemic, our findings imply that this support may also remain relevant for current SCDF paramedics, despite the absence of a public health emergency.

Nevertheless, baseline social support and psychological resilience were high, indicating that local paramedics demonstrated both social and psychological strength throughout the pandemic and in the post-pandemic period. Such high baseline levels may be due to SCDF's regular psychological initiatives aimed at improving staff well-being and mental health literacy (Figure 8). These initiatives are led by SCDF's in-house psychological outfit, the Emergency Psychological Sciences Department (EPSD). EPSD also conducts resilience modules during frontline onboarding and promotes well-being email broadcasts on coping with work stress (Figure 9).

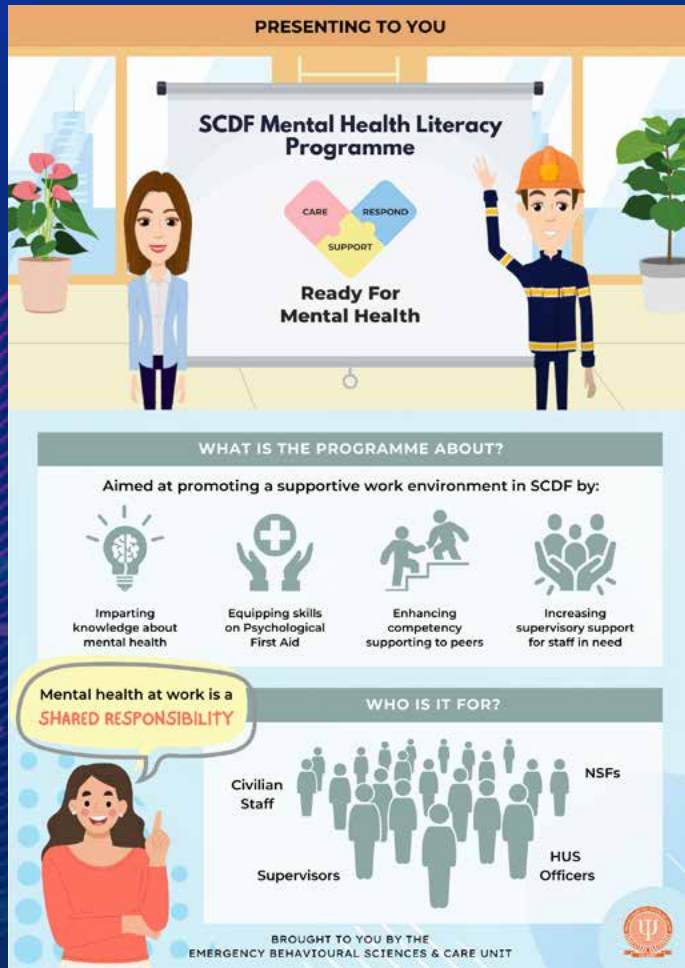


Figure 8: SCDF's Mental Health Literacy Programme for SCDF staff

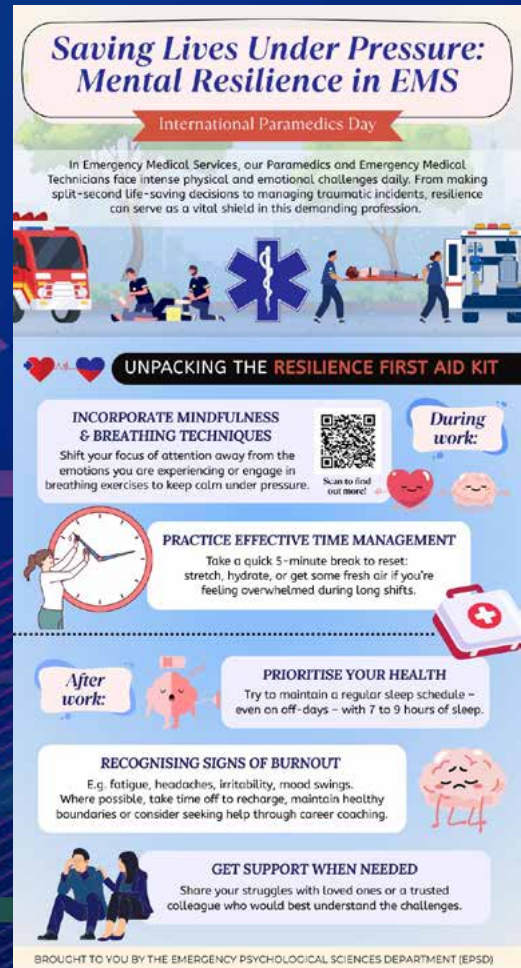


Figure 9: Example of SCDF's well-being broadcast

Additional psychological interventions, such as Oxford-Online, may further enhance resilience and buffer the cumulative effects of a high-stress working environment for paramedics. Following the completion of the study, an in-depth data analysis will be carried out to evaluate the effectiveness of Oxford-Online. Analysis will include examining the differences between baseline and post-intervention stress-related measures for paramedics who went through the Oxford-Online and Mind-Online resilience programmes, respectively. The analysis will also look into the potential implications of incorporating such programmes in supporting frontline responders' well-being and resilience.

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HEAT STRESS MANAGEMENT STRATEGY

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EDITORIAL PREVIEW

The Emergency Responders' Fitness Conditioning and Enhancement Lab (EXCEL) was commissioned at the Civil Defence Academy (CDA) in 2022 to enhance personnel safety and operational readiness. The Responder Performance Centre (RPC) at CDA oversees the operations of EXCEL, which conducts human factors research to optimise training, operational effectiveness, and safety, as well as collaborations to support performance-enhancing research in the Singapore Civil Defence Force. To tackle heat stress systematically, the RPC implemented heat stress management strategies elaborated in this article.

INTRODUCTION

In 2022, the Emergency Responders' Fitness Conditioning and Enhancement Lab (EXCEL) was commissioned at the Civil Defence Academy (CDA) to enhance personnel safety and operational readiness. EXCEL was codeveloped by the Singapore Civil Defence Force (SCDF) and the Home Team Science and Technology Agency (HTX). The Responder Performance Centre (RPC) at CDA oversees the operations of EXCEL, which conducts human factors research to optimise training, operational effectiveness, and safety, as well as collaborations to support performance-enhancing research in SCDF.

Due to the nature of firefighting activities, training and operations are bound to involve high heat stress, physical intensity, and sweat loss. To tackle heat stress systematically, the RPC implemented heat stress management strategies built on four core pillars — (i) Cooling Initiatives, (ii) Training Safety Monitoring, (iii) Work-Rest Cycle Optimisation, and (iv) Heat Acclimatisation Training. This systematic approach ensures SCDF emergency responders can train and perform duties safely and effectively in Singapore's challenging climate conditions.

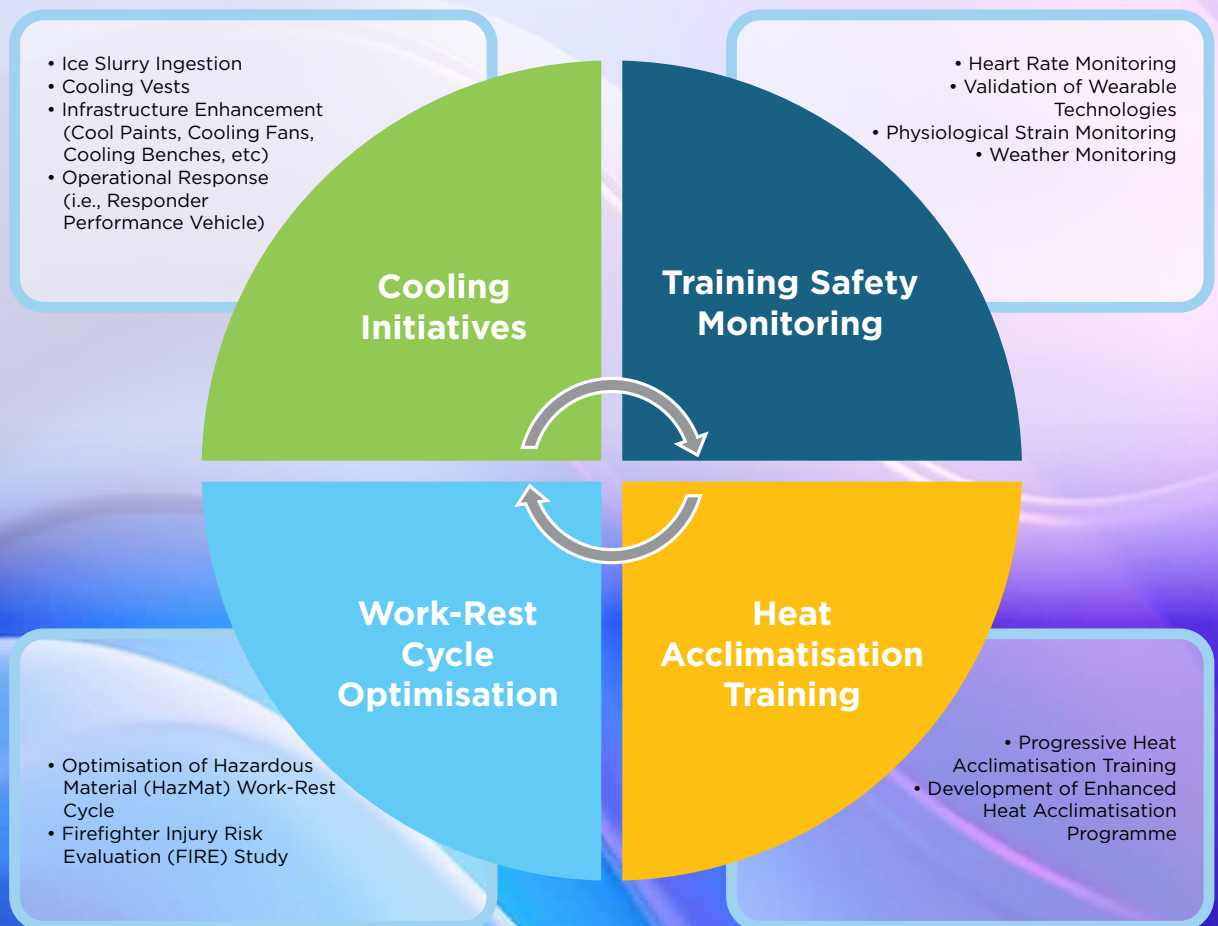


Figure 1: Overview of RPC's heat stress management strategies

COOLING

Heat injuries pose a significant occupational risk for firefighters, necessitating effective cooling interventions to support cooling in various forms. Together, they work to expand heat capacity and lengthen work tolerance.

Ice Slurry Ingestion

An ice slurry is a mixture of very small, crushed ice crystals and liquid of the same substance. It cools more effectively than cold water, as ice has a higher heat capacity than water. Upon ingestion, more heat energy would be required to melt the ice, leaving less energy available to raise the body's core temperature during exertion. Ice slurries can be used as a pre-cooling strategy before exposure to hot environments, delaying the time taken to reach an individual's max core body temperature threshold. Consuming it post-operation can also speed up recovery by lowering body temperature back to baseline and serving as a form of morale boost.

Trials using various ice slurry formulations and delivery methods yielded positive results, including reduced aural temperatures and improved thermal sensation. In July 2024, frozen hydration bars were introduced to support pre-training cooling during high-intensity exercises at CDA and for post-operation recovery at the frontlines through SCDF's corporate support units.



Figure 2: SCDF firefighting trainees consuming hydration bars during training

Cooling Vests and Infrastructure Enhancement

RPC has actively explored and trialled various innovative cooling solutions to improve heat mitigation. One example is the evaluation of cooling vests with differing working principles, such as thermoelectric cooling, fan-based ventilation, phase-change material (PCM), water vapour absorption, water evaporation, and circulating fluid systems. Findings were published under “Personal cooling devices to enhance emergency responders’ thermal resilience” in the Asia-Pacific Fire Magazine in April 2023. Among the options assessed, PCM cooling vests were identified as the most practical for firefighting applications. These vests maintain a constant temperature by absorbing heat from the surroundings during the material’s phase change. They are currently being trialled across various training and operational scenarios to evaluate their suitability and effectiveness.

Additionally, the team has explored infrastructure enhancements aimed at improving environmental conditions during training. These include applying heat-reflective “cool paints” to reduce heat absorption in building walls, optimising airflow and wind thermodynamics within training areas through high-volume low-speed (HVLS) cooling fans, and developing customised cooling chairs and benches. Collectively, these measures aim to improve ambient conditions for both trainees and instructors, creating a more conducive and comfortable training environment.

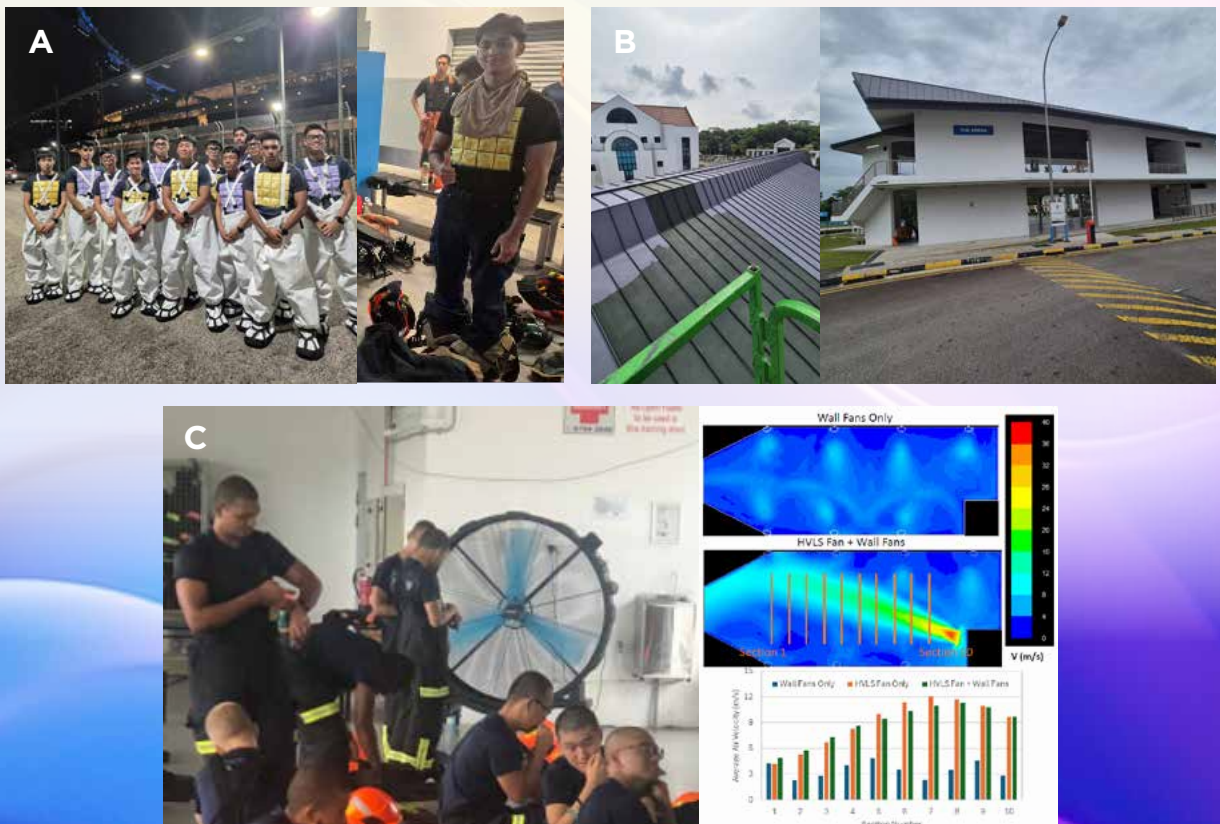


Figure 3: Cooling strategies under trial — (A) cooling vests, (B) training shed with cool paint, (C) cooling fan

RPV

In 2020, SCDF rolled out the Responders Performance Vehicle (RPV), a groundbreaking mobile recovery vehicle designed to manage heat stress and prevent heat injuries during extended emergency operations. This innovation has significantly enhanced frontline responder performance and recovery.

At the front of the vehicle is a triage station where paramedics assess responders for signs of heat injury using aural temperature measurements and the Glasgow Coma Scale. Based on their condition, responders are directed to a suitable cooling zone — Rapid Cooling Zone, Deep Cooling Zone, or Cold Water Immersion. This improves recovery before potential redeployment during high-intensity operations.

Rapid Cooling Zone



Deep Cooling Zone



Cold Water Immersion



Figure 4: Three main recovery areas within the RPV



With technology advancing, RPC is also exploring ways to improve the RPV's effectiveness, such as upgrading recovery chairs of the Rapid Cooling Zone with PCM to enhance cooling efficiency.

Figure 5: Enhanced recovery chair made in collaboration with HTX's HFS CoE

TRAINING SAFETY AND MONITORING

During training and operations, firefighters are subjected to significant physiological stress due to the demanding nature of firefighting and rescue tasks. However, as personnel are encapsulated within their personal protective equipment (PPE), it is challenging for safety officers to detect early signs of heat injury. This underscores the value of incorporating wearable technology for training safety monitoring. By tracking individual physiological data, risks can be identified and interventions can be made before heat-related conditions develop.

During SCDF's yearly Breathing Apparatus Proficiency Test (BAPT), arm-based heart rate monitors are issued upon registration. Safety officers can thus monitor individuals' heart rates while they complete the various stations within the test. Moreover, if personnel reach Heart Rate Zone 5 (90–100% of maximum heart rate), safety officers can promptly assess their condition and initiate rest to prevent potential incidents. Tapping on SCDF's smartwatches and new Wearable Management System, the wrist-based devices used during BAPT also provide real-time visualisation of heart rates and corresponding heart rate zones, further enhancing safety monitoring and intervention capabilities.

To enhance the safety monitoring of firefighting trainees, RPC, in collaboration with the National University of Singapore and HTX's HFS CoE, has explored the application of Physiological Strain Index (PSI). Heat stress can be more accurately measured with PSI as it uses both heart rate and core body temperature. PSI rates heat strain on a scale of 0 to 10, with 0 representing no physiological strain and 10 representing the highest physiological strain. Efforts also involve the development of a customised algorithm tailored to SCDF's firefighters and operating context. These monitoring measures help to enhance workplace safety through the use of quantitative data and reduce the risk of heat-related injuries during firefighting activities.



Figure 6: Dashboard view of heart rate zone monitoring during BAPT

WORK-REST CYCLES

Due to exposure to heat and risk of heat strain during training and operations, work-rest cycles are important in ensuring responders get sufficient rest to reduce the risk of injuries before redeployment.

Using EXCEL's cognitive lab capabilities and SCDF's smartwatches to assess cognitive and physiological performance, respectively, a study was conducted to optimise the work-rest cycle of Hazardous Material (HazMat) specialists wearing level A PPE suits during simulated HazMat operations. The study was conducted in collaboration between the Republic Polytechnic, HTX's HFS CoE, and SCDF. 132 HazMat specialists were randomly assigned to three groups with varying rest durations between two simulated HazMat deployments: 15 minutes of rest, 30 minutes of rest, or 45 minutes of rest. The findings provided interesting insights into the performance of responders vis-à-vis recovery and resulted in the review of the work-rest cycle to optimise it.

Building on experience in reviewing the work-rest cycle of the HazMat Specialist group in SCDF, RPC then extended work-rest cycles research to firefighting operations. The Firefighter Injury Risk Evaluation (FIRE) study was conducted in 2025 in collaboration with the University of Kentucky, Nanyang Technological University, and HTX's HFS CoE. The forthcoming insights will inform the development of work-rest cycles and recovery interventions in SCDF. These developments aim to optimise both physiological and cognitive performance while enhancing the organisation's ability to manage heat stress effectively.

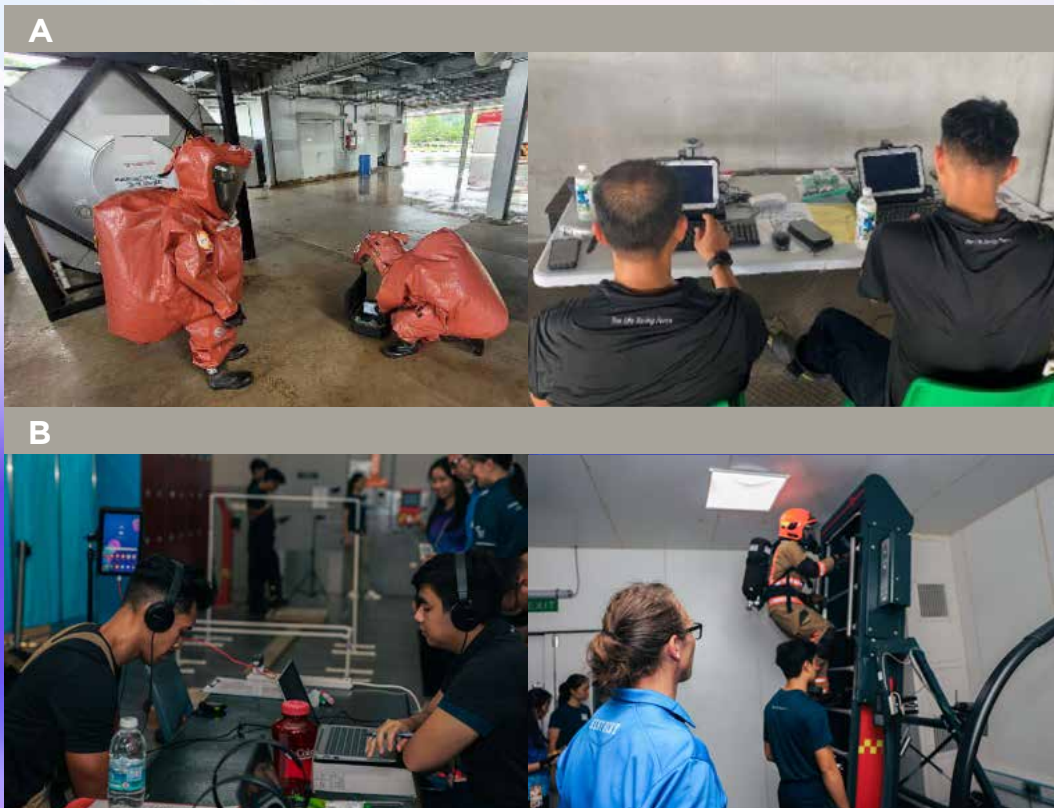


Figure 7: Work-rest cycle trials — (A) HazMat study, (B) FIRE study trials

HEAT ACCLIMATISATION TRAINING

Firefighters often face uncompensable heat stress due to the PPE worn to protect personnel from external heat, flames, and danger. To prepare for operational demands, SCDF trainees undergo a gradual heat acclimatisation programme to build their heat endurance before they begin training for operational scenarios.

Heat acclimatisation is a controlled training process that gradually exposes the body to heat stress, enabling physiological adaptations that enhance thermoregulation, optimise cardiovascular function, and improve overall performance in high-temperature environments. This type of training is especially important for personnel who constantly work in hot environments, such as firefighters, military personnel, athletes, and industrial workers.

Training typically begins with short, low-intensity exposures to heat, which gradually increase in duration and intensity. This allows the body to adapt safely, reducing the risk of heat-related illnesses. It also includes physical activities similar to the job tasks, like aerobic exercises and strength training. SCDF's existing 12-day heat acclimatisation programme builds individual heat tolerance and thermal adaptations, which enhance performance and safety in hot conditions.

Building on the success of the existing protocol and in response to the anticipated increase in environmental heat due to global warming, work is ongoing to develop an Enhanced Heat Acclimatisation (EHA) training programme. The initiative aims to optimise heat acclimatisation while also being adaptable for maintenance training of frontline personnel throughout their service.

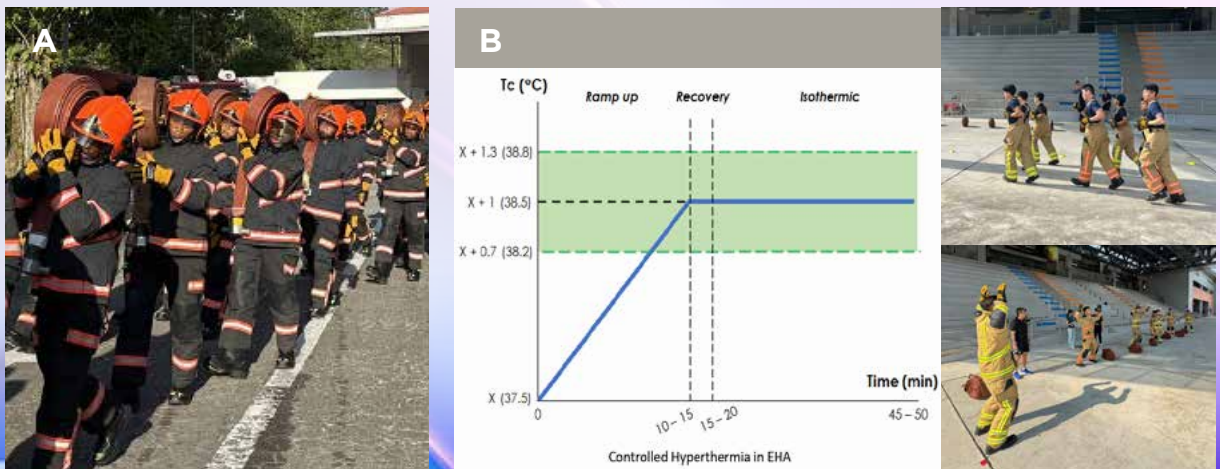


Figure 8: Heat acclimatisation training — (A) current heat acclimatisation programme, (B) enhanced heat acclimatisation programme

CONCLUSION

To recap, SCDF's heat stress management strategy is built upon four comprehensive pillars: Cooling Initiatives, Training Safety Monitoring, Work-Rest Cycle Optimisation, and Heat Acclimatisation Training. The initiatives within each pillar are continually evolving based on technological readiness and RPC's evolving scientific knowledge and approach to assessing and implementing innovations within SCDF. SCDF is committed to enhancing heat mitigation strategies to safeguard frontline emergency responders in novel ways that apply to local and international emergency response units.

SCDF'S SGP-01 OLH INSARAG EXTERNAL RECLASSIFICATION 2025

MAJ Joel Ee

Platoon Commander
Search Platoon
Disaster Assistance and Rescue Team

CPT Wilson Tan

Rota Commander
Disaster Assistance and Rescue Team

EDITORIAL PREVIEW

In 2008, SGP-01 became the first USAR team in the Asia-Pacific region to attain the rigorous INSARAG External Classification (IEC). This set a key milestone in SCDF's benchmarking of its urban search and rescue (USAR) capabilities to an internationally accredited standard for USAR excellence. The team's commitment to maintaining these high USAR standards is further demonstrated by the successful INSARAG External Reclassifications (IER) in 2013 and 2018. SGP-01's dedication to ensuring INSARAG accreditation over the past two decades underlines SCDF's commitment to international humanitarian assistance and disaster relief. With its latest reclassification in August 2025, this article summarises the key highlights and initiatives in SGP-01's third journey towards USAR excellence.

INSARAG¹

The International Search and Rescue Advisory Group (INSARAG) was established in 1991 following the urban search and rescue (USAR) response to the 1985 Mexican earthquake and the 1988 Armenian earthquake. INSARAG is a global network of USAR teams from more than 90 member states with the common mission of rendering effective Humanitarian Assistance and Disaster Relief (HADR) efforts to those affected by natural disasters.

INSARAG is organised into three regional groups, namely: (i) Americas, (ii) Africa-Europe-Middle East, and (iii) Asia-Pacific. The three regional groups meet annually to strengthen regional USAR responses and ensure the implementation and standardisation of strategic directions and policies set by the INSARAG Steering Group, headquartered in Geneva, Switzerland.



Figure 1: World map showing the three regional groups

¹ Refer to <https://insarag.org> for more information.

INSARAG GUIDELINES

Endorsed by the United Nations General Assembly Resolution 57/150 of 2002, on “Strengthening the Effectiveness and Coordination of International Urban Search and Rescue Assistance”, the INSARAG Guidelines are organised into three volumes (see figure 2). The document guide member states in building their capacity to respond to disasters in a structured and coordinated approach, and outline the process for achieving the INSARAG External Classification (IEC) and INSARAG External Reclassifications (IER).

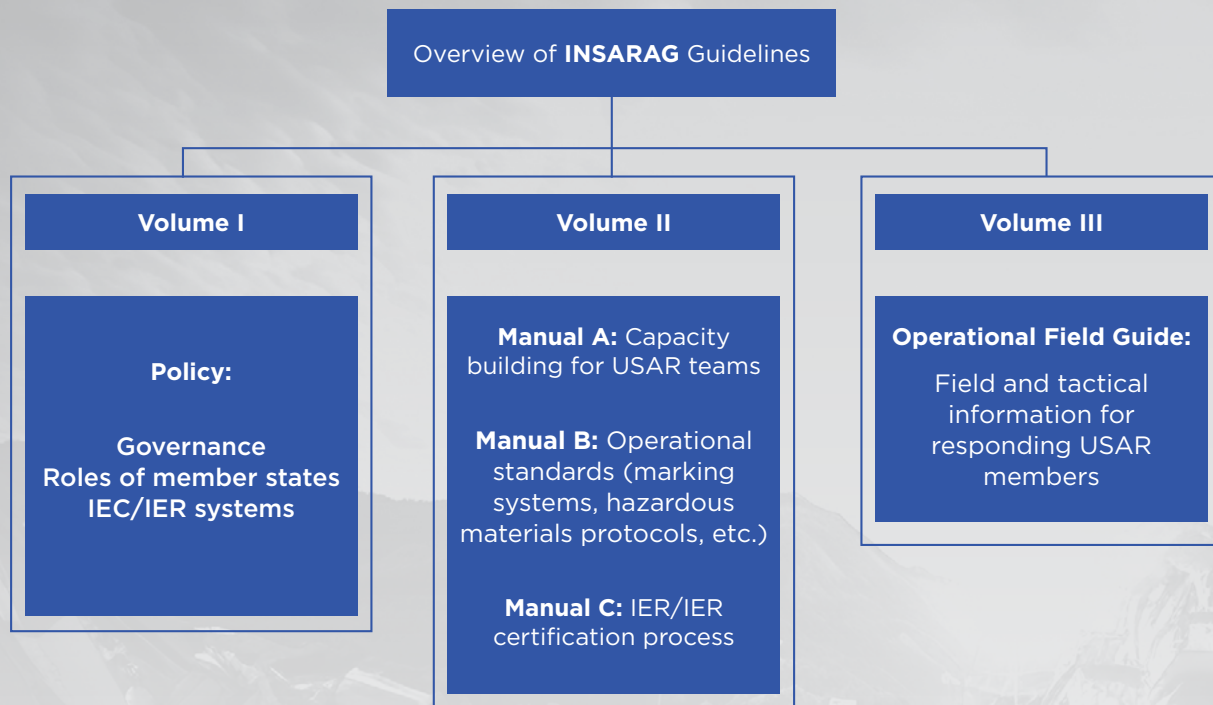


Figure 2: Overview of the INSARAG Guidelines

The IEC is a voluntary, independent, peer-reviewed process that ensures a USAR team meets the minimum standards to respond and operate in accordance with INSARAG Guidelines. As part of INSARAG's accreditation process, classifiers comprising experienced USAR experts from different INSARAG member states are rostered to form classifier teams to conduct independent and objective assessments of USAR teams using the INSARAG certification checklist. The INSARAG Guidelines are binding on all member states. It requires all INSARAG-certified teams to undergo a rigorous re-certification process every five years to ensure continued standards, relevance, and proficiency are maintained by certified teams.

INSARAG USAR TEAM CLASSIFICATION

INSARAG classifies USAR teams as Light, Medium, or Heavy based on their capacity and capability to operate effectively across five key components:

- **Management:** Oversees operations, coordination, and strategic planning.
- **Logistic:** Manages supply, equipment maintenance, and team sustainability.
- **Medical:** Delivers emergency care, triage, and victim stabilisation.
- **Search:** Utilises canine units, technical tools, and reconnaissance to locate victims.
- **Rescue:** Conducts extrication, structural stabilisation, and victim recovery.

Table 1: Key differences between Light, Medium, and Heavy USAR teams

	USAR Team Categories		
	Light	Medium	Heavy
Deployment Duration	Self-sufficient for up to:		
	5 days	7 days	10 days
Worksite coverage	1 worksite, operation up to 12 hours	1 worksite, operation up to 24 hours	2 worksite, simultaneously, operation up to 24 hours
Team Size	17-20 personnel	42 personnel	63 personnel

SCDF'S SGP-01 OLH

Operation Lionheart (OLH) is Singapore's humanitarian mission, led by the Singapore Civil Defence Force (SCDF). The 80-member contingent (including four search canines) stands ready 24/7 to provide USAR and HADR to countries affected by major disasters.

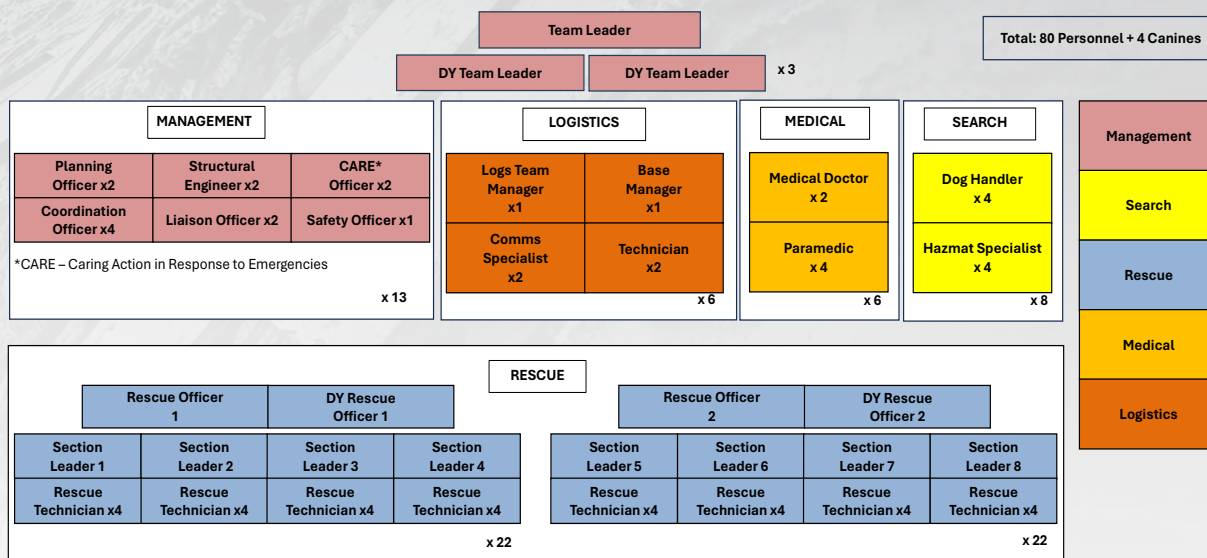


Figure 3: Structure of the 80-member SGP-01 OLH Contingent

SCDF's OLV Contingent, officially designated as SGP-01, is classified as an INSARAG Heavy USAR team. Since its maiden deployment to Baguio City, Philippines, in 1990, SGP-01 has undertaken 21 overseas HADR missions, with the most recent to Naypyidaw, Myanmar, in April 2025. This commitment to HADR efforts across the Asia-Pacific region and beyond reiterates Singapore's commitment and dedication to international cooperation, humanitarian causes, and supporting others in need.



Figure 4: Map of the 21 overseas deployments of SGP-01 (1990 to 2025)

SGP-01'S IER TIMELINE

To prepare for IER 2025, SCDF began a 24-month preparation period to meet key milestones and address areas for improvement identified during the 2018 reclassification. The preparatory period started in 2023, where several lessons learnt from actual deployments, coupled with new capabilities, were incorporated as part of SGP-01's preparatory efforts.

During the preparation phase, SGP-01 submitted its intention to participate in the reclassification. It sought the INSARAG fraternity to appoint an IER mentor who would oversee and guide SGP-01 to meet every line item within the reclassification checklist.

Worth noting, the preparation phase comprised commitment at both the tactical and strategic levels. The tactical aspect involves USAR-related training that sharpens or hones the skill sets of the rescuers making up the contingent; the strategic aspect involves policies that govern the standard operating procedures, the drafting of exercise simulations, equipping, and compliance with all required checklists and mentor reports to INSARAG to affirm SGP-01's readiness for IER.

During the IER, SGP-01 was assessed on the two key components — response capability and technical capacity — based on the revised 2020 IER Checklist from the INSARAG Guidelines. The team must demonstrate compliance with all items stated in the IER Checklist² and the Comprehensive Portfolio of Evidence (C-PoE). SGP-01's IER, which includes the rigorous 36-hour simulated deployment exercise, took place from 19 to 22 August 2025.

² The IEC/R Checklist has been expanded from 15 broad categories (60 items) to 16 broad categories (91 items). USAR Teams undergoing IEC or IER must comply with all items in the checklist.

Table 2: Timeline showing key activities for the IER

IER 2025 TIMELINE

	MONTH	2023												2024												2025											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
		ACTIVITIES																																			
1	Initiation of IER Equipment Purchases							24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0					
2	Delivery of IER Equipment																																				
3	Table IER SMM Paper																																				
4	Engagement of Mentor (24mths)									1st										2nd							3rd						4th				
5	Submission of IER applications (24mths)																																				
6	Formation of IER Sterling Committee																																				
7	Selection of Exercise Body																																				
8	OLH SOP Review																																				
9	Field Exercise Plans																																				
10	Submission of C-PoE (12mths)																																				
11	IER Component Training																																				
12	Classifiers/Observers Plans																																				
13	Video conferencing with Classifiers																																				
14	24hrs/36hrs Exercises															24 hrs				24 hrs							36 hrs			36 hrs							
15	Preparation of Exercise Simulations																																				
16	IER 2025																																			36 hrs IER	
17	Post IER AAR																																				

APPOINTMENT OF SGP-01 IER 2025 MENTOR

As a distinguished member of the New Zealand Order of Merit and a long-standing member of the INSARAG Training Working Group, Mr Paul Burns played a pivotal role as a mentor to SGP-01. With over three decades of experience in emergency response and disaster management with Fire and Emergency New Zealand, Mr Burns brought deep operational expertise in his capacity as Team Mentor to guide SGP-01 through the 2025 IER process.

As part of SGP-01's preparation process, Mr Burns made four functional review visits to Singapore as the mentor for SGP-01's reclassification. Each visit was strategically timed to coincide with key milestones in the team's

preparation, from specific competency-based workshops in USAR Coordination to component-level tactical exercises and even a full-scale 36-hour pre-IER deployment exercise. During these visits, he provided hands-on guidance, conducted technical assessments, and shared global best practices drawn from his extensive field experience.

Mr Burns made his first mentor trip in October 2023 to review SGP-01's readiness. During the trip, he recommended to INSARAG that the team was ready and on track for its IER in August 2025. He then made three more visits to support SGP-01's IER preparations.

Figure 5: Mr Paul Burns being briefed on operational matters during part of the mentor review

Figure 6: Mr Paul Burns being briefed on the vet check process during his first mentor visit



Figure 7: The Training and Professional Development Department presenting the exercise management system during Mr Paul Burns's second mentor visit

His second visit, completed in August 2024, focused on reviewing the C-PoE, the relevant standard operating procedures (SOPs), and the exercise simulation plan. The third visit, in May 2025, centred on overseeing the 36-hour IER full-dress rehearsal and reviewing the itinerary for the classifiers. His fourth and final visit took place in August 2025, where he supported SGP-01's actual IER.



*Figure 8: Mr Paul Burns with key appointment holders at the simulated Base of Operations during his third mentor visit
From left: AC Lim Beng Hui, Mr Winston Chang, AC Chew Keng Tok, DC Ling Young Ern, Mr Paul Burns, SAC Alan Chow Mun Keong*

PREPARATION FROM 2023–2025

To prepare for IER 2025, the after-action review (AAR) findings from 2018's IER were addressed, with a focus on operations and safety. Disaster Assistance and Rescue Team personnel, forming the majority of SGP-01, were routinely rostered to conduct unit-level USAR-related training to strengthen rescuer competencies. SCDF also engaged USAR experts to support the training framework.

Several component trainings were also conducted from 2024 to piece different functional groups together and identify potential gaps. This culminated in a full-scale, 36-hour IER preparatory exercise designed to stress-test SGP-01, including mobilisation, equipping, departure and arrival, Local Emergency Management Authority coordination, base of operations setup, and worksite phases.



Figure 9: SGP-01 member undergoing health screening at the mobilisation centre

These exercises fostered synergy across SCDF departments, with personnel participating as controllers, role players, exercise body, and liaison officers to rehearse the entire exercise management and administrative programme.

Building on SCDF's ongoing effort to regularly assess and refresh operational equipment, key tools required for USAR were replaced. This ensures a fresh fleet of rescue tools, not only for IER but also to ensure mission readiness. Among these tools is the Ring-Saw, which is largely used for cutting and breaking operations. Additionally, SCDF procured new Gen-3 USAR Suits (Figure 11), which are designed with enhanced visibility and ergonomics to improve responders' overall performance, comfort, and safety.



Figure 10: Rescue work during the 36-hour preparatory exercise



Figure 11: Gen-3 USAR Suits

In addition, OLH SOPs were reviewed to streamline processes. IER AAR aside, SGP-01's deployment to Türkiye and Myanmar provided abundant learning takeaways often absent from textbook scenarios. Key updates include formalised arrangements with ST Logistics for commercial flight options, updated contact details and link-up protocols for consular offices across the Asia-Pacific region, and refined nomenclature to clarify roles and functions during joint operations and team meetings.

IER 2025

The IER, which was conducted from 19 to 22 August 2025, included an intensive 36-hour field exercise that stress-tested the contingent on the various complex USAR scenarios replicating real-life deployment. Held at the Civil Defence Academy and the Home Team Tactical Training Centre, a 13-member classification team of disaster response experts from seven countries assessed the contingent's capabilities across the domains (i.e., management, logistics, medical, search, and rescue).

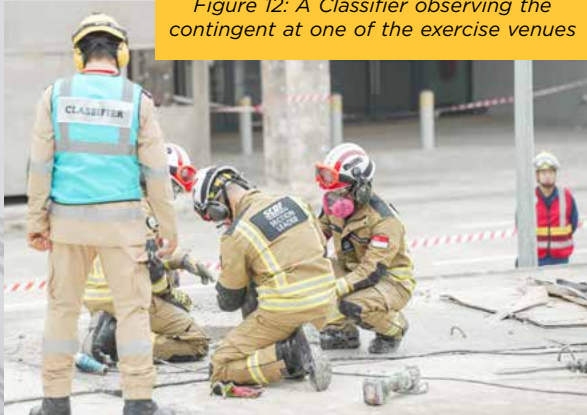


Figure 12: A Classifier observing the contingent at one of the exercise venues

The contingent's ability to conduct technically complex USAR operations in the aftermath of major disasters included operating round-the-clock at two separate worksites concurrently for up to 10 days. The exercise scenario ranged from height rescue and shoring to concrete cutting. Canine capabilities were also deployed to augment the search operations.



Figure 13: Height rescue to lower casualty



Figure 14: Canine search capabilities deployed

OPERATIONS CAPABILITIES SHOWCASE FOR IER 2025

SCDF is committed to achieving operational excellence in both local emergency responses and overseas USAR deployments and continuously innovates to enhance its capabilities. Several pre-identified innovations and proof-of-concept initiatives were integrated into the 36-hour IER Field Exercise, allowing for a comprehensive demonstration of SCDF's innovative capabilities that could aid SGP-01 during deployments. SGP-01's operative capabilities are summarised in Figure 15.



Figure 15: List of operations capabilities

One groundbreaking innovation showcased was the cyborg cockroaches developed in partnership with the Home Team Science and Technology Agency. The Madagascar hissing cockroaches, fitted with infrared cameras and sensors, were first tried and tested during the Myanmar earthquake deployment. These cyborg cockroaches were once again deployed during the IER 2025 on a demarcated worksite to augment conventional search capabilities.



Figure 16: Cyborg cockroach

Another highlight was Tilt-Detect (TILDE). Following a natural disaster such as an earthquake, rescuers performing search and rescue operations constantly face life-threatening dangers from building shifts and aftershocks. Traditional monitoring tools require constant human oversight and lack continuous data transmission. This make it challenging to detect sudden building shifts as they occur. Using a cutting-edge Android application, TILDE, a smartphone can now be used as a monitoring tool. It reduces the need for consistent human intervention, thereby augmenting operations. Moreover, it reduces human error due to fatigue and enables more accurate prompts through automatic detection in real-time.



Figure 18: Structural Engineers utilised TILDE, a mobile application that monitors subtle building movements with a smart tablet

While the list of innovations is extensive, these two examples highlight SCDF's approach to leverage relevant science and technologies to complement rescuer efforts and optimise operational outcomes.

FOSTERING TIES WITH INTERNATIONAL PARTIES

As part of SCDF's ongoing efforts to foster ties with the international USAR community, SCDF invited foreign USAR teams to participate in SGP-01's IER 2025. International teams from the Special Malaysia Disaster Assistance and Rescue Team, Oman Civil Defence and Ambulance Authority, the Hong Kong Fire Services Department, and the Qatar International Search and Rescue Group helped enhance the realism and complexity.



Figure 17: International participants alongside COMR Eric Yap (sixth from left), DC Ling Young Ern (third from right) and SCDF Senior Management/Officers

The international USAR teams were deployed to a USAR worksite that tested collaboration and facilitated the exchange of knowledge and expertise. The exercise resulted in the successful extrication and lowering of the casualty from the ship firefighting simulator.



Figure 19: International participants successfully extricated and lowered the casualty from height

CONCLUSION

On 22 August 2025, the SCDF's 80-member OLH contingent was successfully reclassified by INSARAG as a Heavy USAR Team. SGP-01's reclassification as a Heavy USAR team is the highest level of recognition for international USAR teams and reaffirms OLH contingent's high standards in international disaster response. SCDF will continue to engage actively in INSARAG to fulfil our role as a member of the international USAR fraternity and contribute towards the formulation and shaping of USAR best practices.



Figure 20: Closing ceremony to commemorate the successive reclassification of SGP-01



THE INCREASING RISK OF HOUSE FIRES FROM LITHIUM-ION BATTERIES

Ritchie O' Connell

Wales Representative for BAFA
Fire Safety Consultant
The Fire Practice

The risk of e-scooter and e-bike fires is well documented, with dramatic footage frequently shown on national television and various rail networks prohibiting their carriage. So, we could be forgiven for thinking that the risk is limited only to scooters, bikes, hoverboards, etc.

In fact, the batteries are principally very similar, differing predominantly in size, and the risk also exists in the smaller devices we use routinely. The larger battery packs fitted to micro-mobility vehicles such as e-scooters contain more stored energy, which leads to a concomitant increase in potential fire severity.

The concern is not unwarranted: the London Fire Brigade (LFB) recorded 149 e-bike fires in 2023, and three deaths and 87 e-bike fires in 2022. There have also been fatal fires involving micro-mobility devices, with 11 people killed in fires caused by e-bikes in the UK in 2023.

Many of the fires involving e-bikes have been linked to converting a manual pedal cycle into an e-bike using readily available conversion kits. Of the fires reported by LFB involving e-bikes, at least 40% are believed to have involved a converted e-bike.

Professional conversions using correctly designed and fitted conversion kits sourced from reputable manufacturers and retailers are not inherently dangerous. However, DIY conversions using kits sold online can be appealing and are unlikely to be as safe.

Thermal runaway occurs if the lithium ions create more heat energy than the cell can use or disperse; the heat created then causes a self-sustaining chemical reaction as the battery overheats; the heat transfers to adjacent cells which results in thermal propagation, a chain reaction where adjacent cells are heated to the point that thermal runaway also occurs in these cells — the more cells involved, the greater the heat output, the faster the reaction, and the more rapid the fire development.



The higher the number of cells, the higher the chance of thermal propagation. Once initiated, thermal runaway is irreversible. This is why the battery packs fitted to e-scooters and e-bikes result in larger fires, while smaller batteries such as those in phones, tablets, etc., with fewer cells, are less likely to cause significant damage. Nevertheless, the consequences of a fire or explosion depend largely on where the battery is at the time.

The two principal causes of thermal runaway are physical damage and excess heat. The hazards associated with lithium-ion battery fires include:

- *Explosion*
- *Rapid fire development with the potential for flashover occurring quickly, and exit routes becoming inaccessible*
- *The generation of toxic gases such as hydrogen fluoride and phosphoryl fluoride, as well as asphyxiants such as carbon monoxide*

There have been successful sprinkler stops involving lithium-ion powered mobility devices, such as the successful actuation of a sprinkler head in the West Midlands when a charging e-bike caught fire in a flat. However, the full impact of domestic and residential sprinklers on fires involving lithium-ion batteries is not fully understood. The duration of the water supply may be insufficient to effectively deal with the battery fire throughout its growth and decay cycle. Additionally, there is concern that the very rapid development of a fire and the possibility of an explosion could mean an overwhelmed sprinkler system.



The main benefit of sprinklers in controlling a fire involving a device such as an e-bike would appear to be preventing fire spread to other items. UL's Fire Safety Research Institute (FSRI) is conducting research to test whether residential sprinkler systems can limit the growth of lithium-ion battery-powered e-mobility device fires. Although the full research is not yet published, early results demonstrate that though the device was completely destroyed and there was damage to the room, sprinklers prevented spread to secondary items and ultimately prevented flashover.

Whilst preventing flashover and greater fire spread is a clear benefit, it is by no means a solution. A badly located e-mobility device which catches fire, blocks exits, and produces toxic gases could still cause death or serious injury.

Larger devices, such as scooters, should ideally be stored and charged outdoors, away from any enclosure and clear of exit routes. If they must be stored indoors, they should not be charged overnight and should be located where they do not obstruct escape routes, preferably behind a fire door in an area covered by both detection and suppression.

Sprinklers may have much to contribute to preventing flashover, but a more holistic approach involving regulating the sale of such devices and their component parts, device management, detection, compartmentalisation, and suppression is necessary.

THE MAKE-UP OF A LITHIUM-ION BATTERY

Most portable electrical devices rely on rechargeable power storage (batteries). The most common of these is the lithium-ion battery, which consists of a positive electrode (cathode), a negative electrode (anode), and a porous separator between them. Electrons and lithium ions can pass through this porous layer.

When a battery is charging, lithium ions move from the cathode to the anode. When the battery is unplugged and the device is powered, the process works in reverse. Lithium ions move from the anode to the cathode. Once all ions have reached the cathode, the battery is out of power.

The above process can be repeated through numerous cycles, allowing the battery to charge and power the device far longer than traditional alkaline batteries.

SPRINKLER FRS CAMPAIGN

BAFSA is asking all UK Fire & Rescue Services to get on board with reporting sprinkler activations on their watch to its Sprinkler Saves UK website. Each sprinkler activation saves firefighter time, money, and ultimately lives. The Sprinkler Saves Review 23/24 lists all of the key sprinkler saves that have been reported to BAFSA's Sprinkler Saves UK website over the course of the previous year. The review demonstrates how and why sprinklers make a difference to people, property, and the environment when it comes to fire safety, with real-world examples across a range of fire situations.



CAN AI BE USED IN FIRE SAFETY?

Alex Cox

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EDITORIAL PREVIEW

Artificial intelligence (AI) is an aspect of technology that holds both many advantages and pitfalls for the fire-safety community and the general public, but it is one we cannot ignore. So, what can we expect from its use in fire safety?

FIRE INVESTIGATION

I have, for many years, found that investigating serious or fatal fires is very difficult if you are not part of the investigation team or a relevant authority. This often means that when you examine any official report, it generally raises many questions that the authorities are sometimes reluctant to answer or clarify. To answer these questions, a Freedom of Information (FOI) request to the relevant authority is required. Whilst some authorities are helpful, others can be very guarded in their responses. This leads me to ask: "Why should this be?"

Could it be that the relevant authorities are protecting their own reputation and are unwilling to divulge any information that may show where they have not acted in a manner that was in the interests of the general public or other interested parties? Or could it be that they are covering up mistakes made in dealing with the incident or enforcement? I have always thought that the enforcing authorities should be more open, honest, and transparent in these matters. It is only by adopting an approach like this that we can truly learn from these incidents. This must be in the interests of everyone, not just the enforcing authorities.

Both artificial intelligence (AI) and humans have their own strengths and weaknesses when it comes to fire risk assessments.

- AI can process large amounts of data quickly and efficiently, identify patterns that humans may miss, and make predictions about future fire risks.
- Humans have a deeper understanding of the context and nuances of fire risk assessments, can make judgements to make decisions in complex situations, and can communicate fire risks to others in a clear and concise manner.

The best approach to fire risk assessment is to use a combination of AI and human expertise. AI can be used to identify potential hazards and make predictions about future fire risk, while

humans can use their judgment to evaluate these risks and make decisions about how to mitigate them. It is important to note that the use of AI in fire risk assessments is still in its early stages of development. As AI technology continues to evolve, it is likely to play an increasingly important role in fire risk assessments.

It is interesting to note that in some European countries, investigations are done by the police, who also have forensic science teams available to them.

AI

One of the first questions that I asked AI was, "Can AI be used for fire safety and investigation?" And this was the response:

AI can be used in fire investigation in a number of ways. For example, AI can be used to:

- Identify the origin and cause of fires. AI can analyse data from the fire scene, such as burn patterns, heat distribution and the presence of accelerants, to identify the point of origin and the most likely cause of the fire.*
- Reconstruct the sequence of events leading up to a fire. AI can use data from the fire scene, as well as witness testimony and other evidence, to reconstruct the sequence of events leading up to the fire. This can help investigators to identify suspects and determine whether the fire was accidental or intentional.*
- Predict the behaviour of fires. AI can be used to simulate the behaviour of fires under different conditions, such as wind speed, humidity and fuel type. This information can be used to help firefighters develop effective fire suppression and evacuation plans.*
- Identify fire hazards. AI can be used to analyse data from building inspections and other sources to identify potential fire hazards. This information can be used to develop fire-safety regulations and to help businesses and homeowners to reduce their risk of fire.*
- AI is still under development, but it has the potential to revolutionise fire investigation. By automating tasks that are currently time-consuming and labour-intensive, AI can help investigators to solve fires more quickly and efficiently. Additionally, AI can provide investigators with new insights and perspectives on fire behaviour and fire investigation.*

Here are some specific examples of how AI is being used in fire investigation today:

- Fire investigators are using AI to analyse burn patterns. AI can be used to identify patterns that would be difficult or impossible for human investigators to see. This can help investigators to identify the point of origin of a fire and to determine the most likely cause.*
- AI is being used to reconstruct the sequence of events leading up to a fire. AI can be used to analyse data from the fire scene, such as the location of fire debris and the presence of heat indicators, to reconstruct the sequence of events leading up to the fire. This can help investigators to identify suspects and to determine whether the fire was accidental or intentional.*
- AI is being used to predict the behaviour of fires. AI can be used to simulate the behaviour of fires under different conditions, such as wind speed, humidity and fuel type. This information can be used to help firefighters develop effective fire suppression and evacuation plans.*
- As AI continues to develop, we can expect to see even more innovative and effective ways to use AI in fire investigation.*

So, clearly, there is an important role for AI in fire investigation. However, unless all relevant information is made available, I wonder how accurate the results will be and whether they will be made available to interested parties.



Bibby Stockholm Barge

BIBBY STOCKHOLM BARGE — IS IT SAFE FOR THE INTENDED USE

This is a question that I was recently asked by the British Broadcasting Corporation (BBC). As all the authorities and manufacturers were not being very open about the answer, I decided to ask AI the question. This was the response, but please note that the accuracy of all these responses is not guaranteed:

Fire safety is of paramount importance on board the Bibby Stockholm barge. The barge is equipped with a number of fire-safety features, including:

- *A fire detection and alarm system*
- *Fire extinguishers*
- *Fire hoses*
- *Fire blankets*
- *A fire escape plan*

The crew of the Bibby Stockholm barge are trained in fire-safety procedures and are responsible for maintaining the fire-safety equipment on board. In the event of a fire, the crew will activate the fire-alarm system and extinguish the fire using the fire extinguishers or fire hoses. If the fire is too large for the crew to extinguish, they will evacuate the barge and call the fire brigade.

Here are some additional fire safety tips for the Bibby Stockholm barge:

- *Keep fire exits clear and unobstructed.*
- *Do not smoke or use open flames on board.*
- *Store flammable materials in designated areas.*
- *Inspect fire-safety equipment regularly and make sure it is in working order.*
- *Hold fire drills regularly to ensure that the crew is familiar with the fire safety procedures.*
- *By following these fire safety tips, the crew of the Bibby Stockholm barge can help to prevent fires and ensure the safety of everyone on board.*

I then asked AI: "Is the Bibby Stockholm barge safe for 500 people?", and this was the response:

Whether the Bibby Stockholm barge is safe for 500 people is a matter of debate. The barge was originally designed to accommodate 222 people, but its capacity has been doubled by putting bunk beds in its cabins and converting some communal rooms into dormitories. This has led to concerns about overcrowding and fire safety.

The UK Fire Brigades Union has warned that the barge is a 'deathtrap' and that the government is putting people's lives at risk by using it to house asylum seekers. The union has also expressed concerns about the lack of training and experience of the staff who will be working on the barge.

The Home Office has defended its decision to use the Bibby Stockholm barge, saying that it has been thoroughly inspected and is safe to accommodate 500 people. The Home Office has also said that the barge will be staffed by experienced and qualified staff.

Ultimately, whether the Bibby Stockholm barge is safe for 500 people is a matter of opinion. There are valid concerns about overcrowding and fire safety, but the Home Office has insisted that the barge is safe.

It is important to note that the Bibby Stockholm barge is currently being used to house asylum seekers. Asylum seekers are particularly vulnerable people who are often fleeing persecution and violence. It is therefore essential that the Home Office takes all necessary steps to ensure that the Bibby Stockholm barge is a safe and humane place to live.

Clearly, in this example, AI is not able to fully answer the question, but does provide a good overview.

THE ROYAL CLARENCE HOTEL FIRE

This is an incident I know a little more about, as I investigated it for BBC. A subsequent programme was shown on BBC's Inside Out, and the results of my investigation were also published on <https://www.ifsecglobal.com/global/frs-report-royal-clarence-hotel-fire-full-holes-missing/>.

Following this, I was contacted by one of the fire officers who attended the fire and indicated that my investigation was closer to the truth than the official report. This led to the production of two BBC programmes that detailed investigations into the firefighting operations, together with eyewitness reports, that also contradicted the official version.

The AI version gave the following response regarding the incident:

Dave Jones, a former sector commander of Devon and Somerset Fire and Rescue Service (DSFRS), believes that the hotel could have been saved by the fire service. He claims that he told incident commanders that he had found a fire on the third floor, but that his evidence to an inquiry was left out of a fire service report.

Jones says that he needed authority to send crews back into the hotel, but that he was met with blank stares. He also claims that 90% of the hotel was perfectly intact, and that it could have and should have been saved.

An independent review into the fire concluded that it remained speculative as to whether the historic hotel could have been saved. However, the review did make a number of recommendations for areas of learning for future incidents dealt with by Devon & Somerset Fire and Rescue Service.

Devon and Somerset Fire and Rescue Service has denied any wrongdoing and says that it hopes the review will reassure the public. However, Jones' claims have raised serious questions about the fire service's handling of the incident.

I would add that I also received a number of other responses from serving members of DSFRS that confirmed Dave Jones' version of the story, but were unwilling to be named due to possible action by their employers.

HOW CAN WE DEVELOP AI TO BE MORE HELPFUL IN FIRE SAFETY?

This is what AI tells us:

There are a number of ways in which we can develop AI to be more helpful in fire safety. Here are a few examples:

Improved fire detection: AI can be used to develop more sophisticated fire-detection systems that can detect fires earlier and more accurately than traditional systems.

This can be done by using AI to analyse data from a variety of sources, such as smoke detectors, heat sensors and cameras.

Predictive fire prevention: AI can be used to develop predictive models that can identify potential fire hazards and predict where and when fires are likely to occur. This information can then be used to prevent fires from happening in the first place.

Firefighting assistance: AI can be used to develop systems that can assist firefighters in fighting fires. This can be done by providing firefighters with real-time information about the fire, such as its location, size and intensity. AI can also be used to develop robots that can help firefighters to extinguish fires and rescue people.

Here are some specific examples of AI-powered fire-safety technologies that are currently being developed:

- *AI-powered smoke detectors: these detectors can use AI to identify different types of smoke, including smoke from different types of fires. This can help to reduce false alarms and improve the accuracy of fire detection.*
- *AI-powered fire surveillance cameras: these cameras can use AI to detect fires and smoke in real time. They can also be used to track the movement of fire and smoke, which can help firefighters to better understand how a fire is behaving.*

- *AI-powered fire prediction models: these models can use data from a variety of sources, such as weather data, building data and historical fire data, to predict where and when fires are likely to occur. This information can be used to prevent fires from happening in the first place, or to deploy resources more effectively in the event of a fire.*
- *AI-powered firefighting robots: these robots can be used to extinguish fires, rescue people, and explore dangerous environments. They can also be used to collect data about fires, which can help firefighters to better understand how fires behave and how to fight them more effectively.*

These are just a few examples of how AI can be used to improve fire safety. As AI technology continues to develop, we can expect to see even more innovative and effective fire-safety solutions emerge.

In addition to developing new AI technologies, we also need to make sure that existing AI technologies are used safely and effectively in fire-safety applications. This means developing and implementing best practices for the development, deployment and use of AI-powered fire-safety systems. It also means educating firefighters and other fire-safety professionals on how to use AI-powered fire-safety systems safely and effectively.

By developing and using AI responsibly, we can make a significant contribution to improving fire safety and reducing the loss of life and property due to fires.

CAN AI BE USED TO CARRY OUT FIRE RISK ASSESSMENTS?

This was another question that I asked AI, and this was the response:

AI can be used to carry out a Fire Risk Assessment (FRA). FRA is a process of identifying and evaluating the fire risks in a building or structure, and then developing a plan to mitigate those risks. AI can be used to automate many of the tasks involved in FRA, such as:

- *Identifying potential fire hazards: AI can be used to analyse building plans and other data to identify potential fire hazards, such as flammable materials, electrical wiring and heating systems.*
- *Evaluating the risk of fire: AI can be used to evaluate the risk of fire based on the identified hazards, as well as other factors such as the occupancy of the building and the fire-safety measures in place.*
- *Developing a fire-risk mitigation plan: AI can be used to develop a fire-risk mitigation plan that includes measures to reduce the likelihood of fire, as well as measures to protect people and property in the event of a fire.*
- *AI-powered FRA tools can help businesses and organisations to save time and money, and to improve the safety of their buildings and occupants.*

However, it is important to note that AI-powered FRA tools are not a replacement for human expertise. It is still important to have a qualified fire-safety professional review the results of any AI-powered FRA and to provide guidance on the implementation of the fire-risk mitigation plan.

Here are some of the benefits of using AI for FRA:

- *Accuracy: AI can be trained on large datasets of fire-safety data to identify fire hazards and assess fire risks with a high degree of accuracy.*
- *Efficiency: AI can automate many of the tasks involved in FRA, which can save businesses and organisations time and money.*
- *Objectivity: AI is not susceptible to human biases, which can help to ensure that FRA is conducted in a fair and objective manner.*

However, there are also some challenges to using AI for FRA:

- *Data quality: AI-powered FRA tools are only as good as the data they are trained on. It is important to ensure that the data used to train the AI is accurate and up to date.*
- *Transparency: it can be difficult to understand how AI-powered FRA tools make decisions. This can make it difficult to trust the results of the assessment.*
- *Accountability: if a fire occurs, it is important to be able to determine who is responsible for the failure of the FRA. This can be difficult to do if the FRA was conducted by an AI.*

Overall, AI has the potential to be a valuable tool for FRA. However, it is important to be aware of the challenges involved in using AI for FRA and to take steps to mitigate those risks.

CONCLUSION

I have spent nearly 60 years in the fire and safety profession. Without doubt, this is one of the most exciting developments I have seen in my career. But, as with all new technology, it will require collaboration from everyone in the industry, especially fire and rescue services, who need to be more open, honest, and transparent in their actions. I have also been discussing AI with my colleagues in Europe, and they are also seeing this as a great step forward. As can be seen from the potential development areas, there is hardly an aspect of fire safety where AI cannot be a useful tool. However, we need to be careful that it does not take over because, at present, we cannot guarantee the results.

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