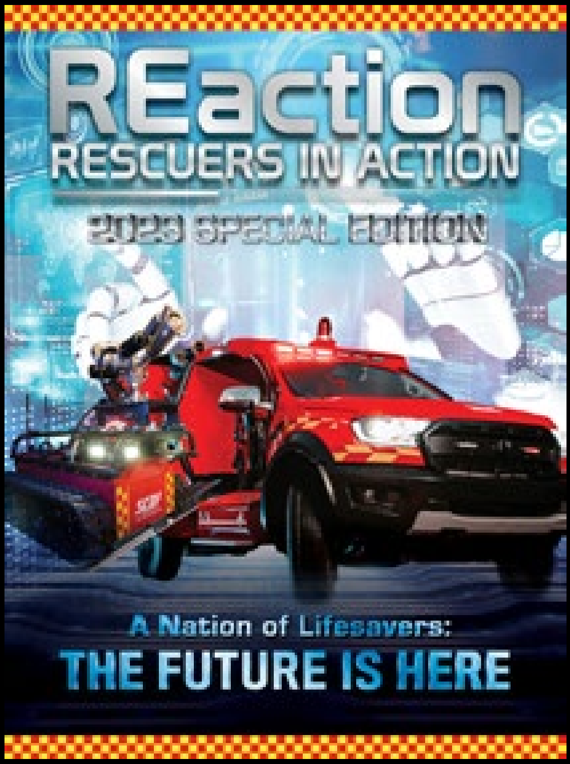
REaction
RESCUERS IN ACTION

2023 SPECIAL EDITION

A Nation of Lifesavers:
THE FUTURE IS HERE



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.

Please address all contributions and correspondence to:

Editorial Board (Attn: CPT Mohamed Noor Hafiz)
Civil Defence Academy,
101 Jalan Bahar, Singapore 649734

For comments and feedback, please email to:
SCDF_CDA@SCDF.gov.sg

EDITORIAL BOARD

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COMMISSIONER'S FOREWORD

Training and learning forms the foundation of every successful organisation, and in SCDF, the Civil Defence Academy (CDA) undertakes that pivotal role. CDA is currently undergoing redevelopment to transform the training and learning experience for our officers. The year 2022 saw the launch of the Emergency Responders' Fitness Conditioning & Enhancement Laboratory (EXCEL) in CDA, marking the completion of phase 1. EXCEL is the first of its kind in the global firefighting fraternity that leverages science and technology to enhance and optimise the performance and safety of our responders.

Phase 2 is the largest of the three phases and, when completed in 2023, will comprise a Fire Research Centre and a myriad of facilities depicting mixed-used premises, shophouses, an underground MRT station and a road tunnel. We will also see the establishment of the National EMS Training Centre (NETC) in phase 2 for end-to-end pre-hospital emergency care training and the continual recertification of all EMS personnel. Phase 3 will entail the redevelopment of the existing furnace with the inclusion of new simulators for joint fire and rescue and EMS training. Phases 2 and 3 are expected to be operational from August 2023 and January 2024 respectively.

On the operations front, SCDF will deploy a pair of new emergency vehicles that will take our firefighting and rescue capabilities to new heights. Reaching up to 90m – equivalent to a 30-storey building – the High-Level Articulated (HLA90) fire and rescue vehicle was unveiled at the Fire Safety Asia Conference (FiSAC) held in November 2022. This capability provides SCDF with additional options for fire and rescue operations in high-rise buildings. On robotics, the 3R (Red Rhino Robot) 2.0 will be progressively introduced in the new LF6G vehicles. Together with the PFM (Pumper Firefighting Machines) robots, they will form the Tier 1 robotics capability of our Basic Task Force. Tier 2 heavy firefighting robots such as the UFM (Unmanned Firefighting Machines) and H3M (High Mobility Modular Machines) can be called upon under our Enhanced Task Force response.

Notwithstanding the vast technological transformation SCDF has introduced over the years, we cannot rest on our laurels. SCDF will continue to innovate to enhance our operational capabilities and hone our professional skills as an emergency response organisation. Let me also take this opportunity to express my appreciation to the authors that have contributed to this REaction edition. I wish everyone an insightful read. Stay safe and keep well!

Eric Yap
Commissioner
Singapore Civil Defence Force

DIGITALLY TRANSFORMED: AN AGILE AND DATA-DRIVEN LIFE SAVING FORCE

LTC Ellena Quek
Senior Assistant Director (Plans & Policy)
Transformation & Future Technology Department

CPT Syafiq Ong
SO Innovation Development
Transformation & Future Technology Department

EDITORIAL PREVIEW

In tandem with its 2025 transformation vision of “A Nation of Lifesavers”, the Singapore Civil Defence Force (SCDF) is digitally transforming its core services and processes to stay ahead of the ever-changing operating landscape.

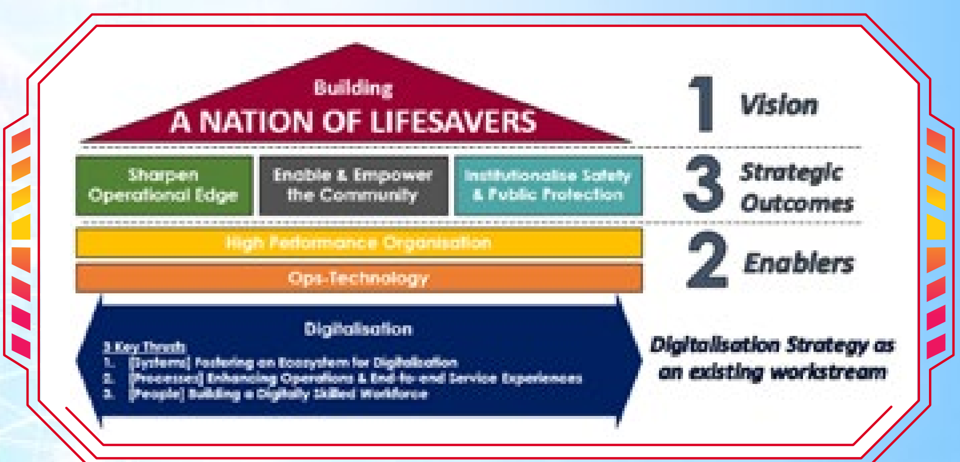
This article explores why digital transformation is applicable to an emergency service organisation and why it matters to the people it serves. It examines how SCDF will augment its frontliners to be operationally ready and digitally equipped to respond to dynamic operating environments, move upstream to encourage self-regulated compliance to fire safety standards, and empower the community through collaboration and tailored engagement. As we evolve our ways of working, we chart novel and innovative pathways towards maintaining our position as a World-Leading Life Saving Force.

WHY CHANGE?

SCDF's transformation vision is set against a backdrop of complex and intertwining factors including an ageing Singapore population, changing public expectations and social norms, evolving operating environments due to rapid and disruptive industry innovations, and threats of climate change and global pandemics. It demands us to question ourselves – how can SCDF take proactive interventions to shape the future we want to operate in?

The two key enablers of SCDF's transformation are the harnessing of Operations-Technological innovations to develop new capabilities and infusing them across our operations and work processes; as well as the nurturing of a High-Performance Organisation by re-engineering our operating models, streamlining processes, and optimising our manpower resources to achieve higher effectiveness.

In turn, these will achieve three strategic outcomes – Sharpening Operational Edge to ensure our operations remain effective to meet future demands while managing resource constraints; Institutionalising Public Safety and Protection by reinforcing upstream fire safety prevention and public protection across the built environment; and Enabling and Empowering the Community by fostering greater ownership within the community as our strategic partner in ensuring safety and security in the neighbourhood, workplace, and recreational areas and render timely intervention as Community First Responders (CFRs).



Enabling proactive and anticipatory actions requires foresight and intelligence, fuelled by data. Data, touted as the new oil, has the ability to create a valuable entity through data analytics that will allow SCDF to deliver increased value to its users and customers. This is especially so within the global context of the fourth Industrial Revolution[1] and the advent of Web 3.0,[2] where businesses increasingly adopt new digital technologies to empower data-driven decision-making processes. By being "digital to the core", SCDF will be able to synergise data and leverage the interoperability and interconnectivity of high computational powered systems, thus decisively transforming the way we respond to emergencies and serve the community.

[1] The fourth Industrial Revolution, also known as Industry 4.0, is characterised by the connectivity of "embedded systems and smart production facilities to generate a digital convergence between industry, business and internal functions and processes. The key technologies driving Industry 4.0 include Internet of Things (IoT), cloud computing, artificial intelligence and machine learning, edge computing, cybersecurity, and digital twin. These allow large amounts of valuable data to be collected, analysed, and exchanged rapidly and securely.

[2] Web 3.0 is the next generation of decentralised internet focused on interaction and collaboration between humans and machines. Users can enjoy a more personalised and interactive experience with improved privacy and security. The key technologies driving Web 3.0 include artificial intelligence, natural language processing and blockchain.

While our digital transformation will not happen overnight, SCDF has taken decisive and proactive interventions to shape the future we want to operate in. In 2021, we conducted a digital transformation consultancy study to objectively align the various stakeholder groups towards a concerted roadmap for Ops-Tech capability development. This involved mapping the digital transformation of SCDF's services and business processes in the areas of Emergency Response and Public Safety, and establishing the Enterprise Architecture (EA)[3] needed to enable the digitally transformed services. This also resulted in the re-design of cross-cutting capabilities and corporate services such as training, professional development, human resource, logistics, knowledge management, and risk management, which enable the delivery of SCDF's services and business processes.

Relevant stakeholders were deeply involved throughout the consultancy study. Leaders participated in strategy and visioning workshops to steer and provide high-level guidance to working committees and endorse the master planning of roadmaps. Internal stakeholders from various SCDF staff departments and frontline units; external stakeholders from related public agencies, including Home Team Science & Technology Agency (HTX) and Building & Construction Authority (BCA); and customers such as fire safety managers and Registered Inspectors were also involved in information gathering and design thinking workshops to analyse the capability gaps in the "as-is" state of service journey maps and blueprints and to co-design the "to-be" business capability masterplan. Internal communications efforts such as a digital diary to crowdsource creative ideas from our staff and the organisation of technology webinars, innovation talks and transformation townhalls were important as they gradually inspired and ignited behavioural and mindset shifts to welcome the changes ahead.

THE FUTURE OF EMERGENCY SERVICES IN SINGAPORE IN 2025 AND BEYOND

SCDF is staying ahead of the game to evolve in tandem with an ever-changing operating landscape beyond 2025. We see our digitally transformed future as agile, data-driven, and customer-centric. Digital technologies will be fused into every aspect of our response, from pre-response where smart buildings and sensors provide continuous real-time situational awareness to the response itself where data analytics and artificial intelligence (AI) solutions recommend response pathways to post-response where data is analysed for improvements in an operational insights feedback loop. At the heart of all these will be our Intelligent Core, a central engine where data from single sources of truth are ingested for processing, pattern discovery and analytics to generate new data-driven capabilities for service delivery, command and control, and predictive readiness.

Powered by such an Intelligent Core, our roles will shift further upstream. SCDF will become an **Intelligent Guardian** that harnesses the power of big data to enhance the provision of services to ensure the safety and security of lives and property; a **Trusted Advisor** that impactfully safeguards the community's interests by influencing customer-centric policies and fostering compliance; and a **Community Advocate** that strengthens the spirit of partnerships in an inclusive ecosystem to enhance community connectivity.

In our operations, digital transformation will impact how citizens interact with our services. When an incident occurs, an AI-driven sensemaking platform draws critical real-time sensor data around the island, enabling the SCDF Operations Centre to dispatch the best-fit SCDF resources and CFRs based on experience and expertise. Members of the public will receive timely alerts via the enhanced myResponder mobile application to stay safe and respond as CFRs when they are within the vicinity of medical or fire cases. Data insights from traffic systems, body-worn cameras donned by our officers and National Electronic Health Records are consolidated to provide a holistic situational picture that will inform appropriate and effective decisions to mitigate dangers. As such, victims can be assured to receive assistance more rapidly and benefit from seamless end-to-end quality care.

[3] EA is a methodology to continually align the design, planning and implementation of business strategy, services and technological capabilities through actionable master plans to achieve a concerted envisioned future state of business. An EA practice typically covers following components – (i) Business architecture; (ii) Data architecture; (iii) Application architecture; and (iv) Technology architecture. EA generally entails a process of working with a diverse set of internal and external stakeholders to document a current-state "as-is" baseline architecture, envision a desired future state "to-be" target architecture, and to develop an actionable roadmap to transit from the baseline to the target state.

SCDF 2025 AND BEYOND

Agile | Data-Driven | Customer-Centric

1 ALWAYS ON / PRE-RESPONSE

INTELLIGENT CONNECTED SYSTEM

An intelligent core that builds on comprehensive sensor data to detect and preempt escalating situations across the nation.

Connected buildings and environment data for real-time monitoring
Connects building sensors for real-time monitoring to enable early detection as well as proactive upstream prevention.

Continuous refinement of prediction models
Adapts models and thresholds to build stronger sensor networks with preventive capabilities.

2 DURING EMERGENCY RESPONSE

COMPREHENSIVE REAL-TIME SITUATIONAL AWARENESS

Building navigation, prediction of fire source & real-time water level update
Building blueprint data and firefighters' wearable devices provide data for effective & safer decision-making.

Predicts impact of fire and human traffic, makes recommendations on optimal team & fleet
Connected with ecosystem to enable adaptive response optimisation.

Drones monitor situation to enable more accurate response prediction and activation

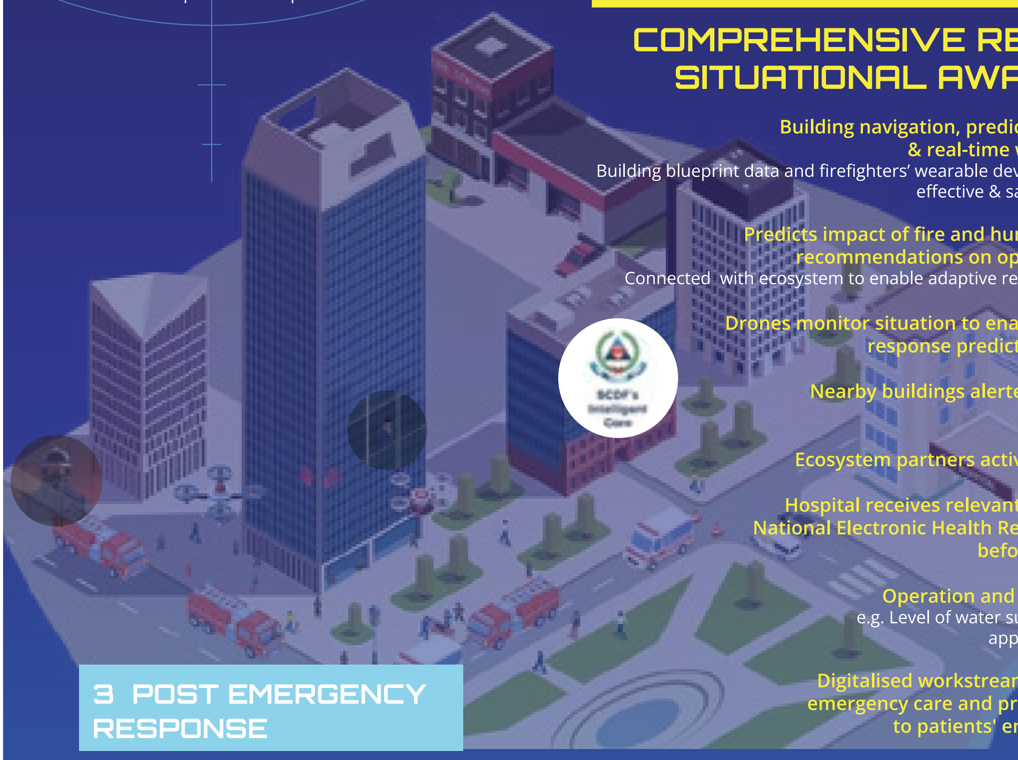
Nearby buildings alerted on fire, receives direction to safety

Ecosystem partners activate their partners

Hospital receives relevant patient vitals and National Electronic Health Records (NEHR) data before patient's arrival

Operation and performance data
e.g. Level of water supply, fuel utilisation, appliance readiness, etc.

Digitalised workstreams for pre-hospital emergency care and provision of updates to patients' emergency contacts



3 POST EMERGENCY RESPONSE

OPERATIONAL INSIGHTS FEEDBACK LOOP

Operational data and insights are ingested into the intelligent feedback loop for refinement of operations and training plans.

Next, being digital-first will redefine interactions on the regulatory front. Fire safety professionals will benefit from a one-stop digital portal that provides intelligent tools to visualise regulatory requirements and streamline submissions of fire safety-related documents, hence reducing downstream rectifications or rejections. Fire safety products such as fire-rated doors and fire alarm panels can be validated online via secure ledgers to ensure the authenticity of installations within buildings. Consultation with professional bodies on the Fire Code and its technical requirements will become more accessible. These customer-centric policies safeguard the community's interests by influencing compliance and inculcating self-regulatory behaviours within the industry.

In the community, enhanced SCDF web portals and mobile applications create meaningful interactions and tailored engagements throughout citizens' different phases of life as active CFRs. For example, students could receive tailored educational resources on emergency preparedness to build awareness and exposure from a young age. As they grow older into working adults, they can benefit from safe and immersive training on a digital learning platform to build up competencies in lifesaving skills such as performing cardiopulmonary resuscitation and using a fire extinguisher, all at their own convenience of time and place. They will also receive recommendations to participate in community initiatives based on their interests and skills. When they retire, they will have gained sufficient competencies and experiences to inspire the next generation of community lifesavers and build an ecosystem that is self-sustaining. Throughout this life cycle, CFRs also contribute coordinated responses to incidents within the community through the myResponder application on mobile, strengthening the spirit of partnerships in an inclusive ecosystem to enhance community connectivity.

BUILDING STEPS TOWARDS OUR INTELLIGENT CORE

Many initiatives are underway to achieve our vision. SCDF is building up our sensor networks and analytics platforms – these form the foundation of our Intelligent Core. We will use Internet of Things (IoT) technologies pervasively, linking smart devices issued to all our officers to our incident management backbone. A platform approach is being adopted for the development of future systems, emphasising connectivity and ecosystem-building, and enabling the organisation-wide throughflow of data that is necessary for our Intelligent Core.

SCDF is starting up its AI Digital Factory, where data analytics are incrementally developed, each leveraging previous models and progressively coalescing into the Intelligent Core that powers SCDF's decision-making. Data analytics will progressively allow us to adopt a risk-based approach, for example, to carry out fire safety inspections of buildings in a more targeted manner by focusing on those located at higher-risk premises and to concurrently reduce the number of buildings that may have not been inspected for a stipulated number of years. With a more sophisticated enforcement framework inculcating such initiatives, a multitude of preventive measures can be realised to enhance Singapore's public safety landscape while at the same time achieving more optimal use of limited organisational resources.

INTELLIGENT CORE

NEXT-GEN SENSEMAKING NETWORK FOR ENHANCED PUBLIC SAFETY

CONNECTED ECOSYSTEMS

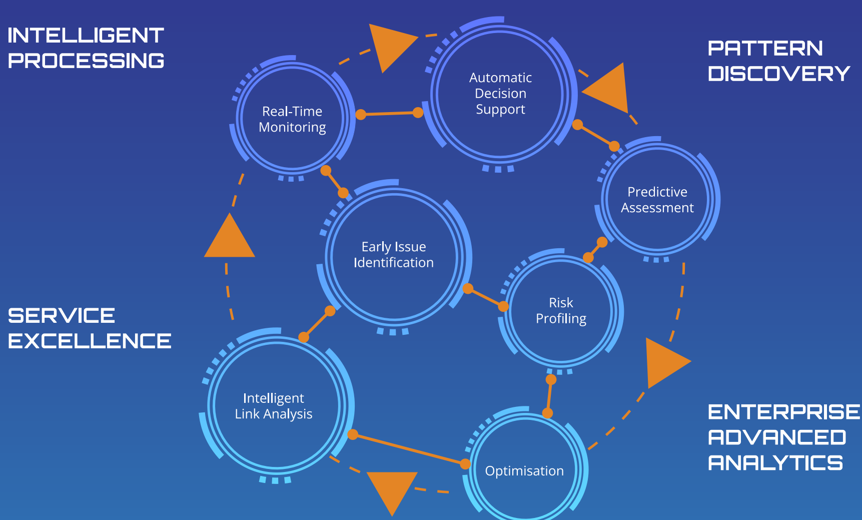
- SCDF CASE INFORMATION
- TRAFFIC MONITORING
- OFFICER VITALS MONITORING
- HEALTHCARE RECORDS
- OPEN SOURCE INFORMATION
- IOT SENSOR INFORMATION
- OFFICER WEARABLES
- MYRESPONDER FEED
- PRODUCT TESTING REPORTS
- BUILDING BLUEPRINTS

REAL-TIME LIVE STREAMING

INTELLIGENT ANALYTICS SUPPORT

- Natural Language Processing
- Anomaly Detection
- Computer Vision
- Recommendation Engine

INTELLIGENT CORE



DATA AS THE LIFEBLOOD

NEW DATA-DRIVEN CAPABILITIES

- INTELLIGENT SENSEMAKING
- ANTICIPATORY SERVICE DELIVERY
- SMART PROFILING & TARGETING
- SEAMLESS COMMAND AND CONTROL
- FORWARD-EDGE DECISION MAKING
- NETWORKED INFORMATION EXCHANGE
- REAL-TIME SITUATIONAL AWARENESS
- PREDICTIVE FORCE READINESS

CONCLUSION

With the conclusion of the consultancy study in early 2022, SCDF has already partnered HTX and industry partners to realise the new business capabilities required to enable us to be agile, data-driven, and customer-centric. Indeed, it is through harnessing the power of our community and industry stakeholders that we can continue to stay ahead of the game and achieve our transformation vision of “A Nation of Lifesavers” in 2025 and beyond.

TRANSFORMING LOGISTICS MANAGEMENT IN SUPPORT OF SCDF OPERATIONS

AC Wesley Ho
Director
Logistics Department

LTC Neo Jia Qi
Senior Assistant Director (Plans & Policy)
Logistics Department

LTA Sion Teo
SO Ops Contracts
Logistics Department

EDITORIAL PREVIEW

This article discusses how the Logistics Management System of SCDF has been a vital operational enabler towards SCDF achieving mission success. In this article, we show how logistics delivery and support has evolved over the years, embracing technology as it matures to better enhance its capabilities. Due to the nature of SCDF's operations as an emergency services provider and responding to incidents every day of the year, there is a fundamental difference in how logistics support is required for operations as compared to other logistics departments and companies. To better support SCDF's operations, three different levels of logistics support were introduced and would be further elaborated in this article. Finally, the article will introduce various logistics initiatives, and elaborate on the focus areas identified to guide SCDF's logistics transformation moving forward.

INTRODUCTION

Logistics is a critical function in ensuring SCDF's continued excellence in executing its mission of protecting and saving lives and property for a safe and secure Singapore. The success of logistics is essential as logistics affects every aspect of the organisation, including training, equipping, and deployment during an emergency.

From the usage of traditional forms of pen and paper for logistics functions to having advanced systems aiding logistics officers in making the most prudent and timely decisions, this article discusses how the Logistics Management System in SCDF has successfully evolved to become a vital operational enabler towards achieving mission success. It also introduces the various logistics initiatives implemented and elaborates on various focus areas identified to guide SCDF's logistics transformation journey ahead.

STRUCTURAL RE-ORGANISATION TO BETTER MEET FRONTLINE NEEDS

SCDF has been continually enhancing its logistics management. In the early years, all logistics functions were handled by a single department, under which there were various branches and Service Support Units (SSUs) that were tagged to the respective Divisions and CDA. In 2019, the five SSUs were centralised into two Corporate Service Hubs (CSH), which also provide all forms of corporate service support to the units, including logistics support. The merger serves to enhance resource utilisation and minimise variation in the service standard delivery across SCDF.

With this transition, there are now three tiers of logistics support: a) the in-situ team, b) the CSH HQs and c) HQ Logistics Department. The in-situ team is a dedicated team which is forward deployed at each Division and oversees the day-to-day support of the various units. During planned events and contingencies, the in-situ team provides immediate logistics support for the units, supervised and reinforced by the CSH HQ. This frees up the HQ Logistics Department to oversee the logistics requirements of the entire force during a crisis. During peacetime, this will also allow the HQ Logistics Department to focus on reviewing logistics policies and processes, enhancing procurement processes, and enhancing governance of logistics functions across SCDF.

SCDF'S OPERATIONAL SUPPORT SYSTEM

As an emergency response service, SCDF relies heavily on a wide array of firefighting, rescue as well as medical equipment in its mission to save lives and property. The typical tiers of logistics support in an operational scenario can be broken down into three layers.

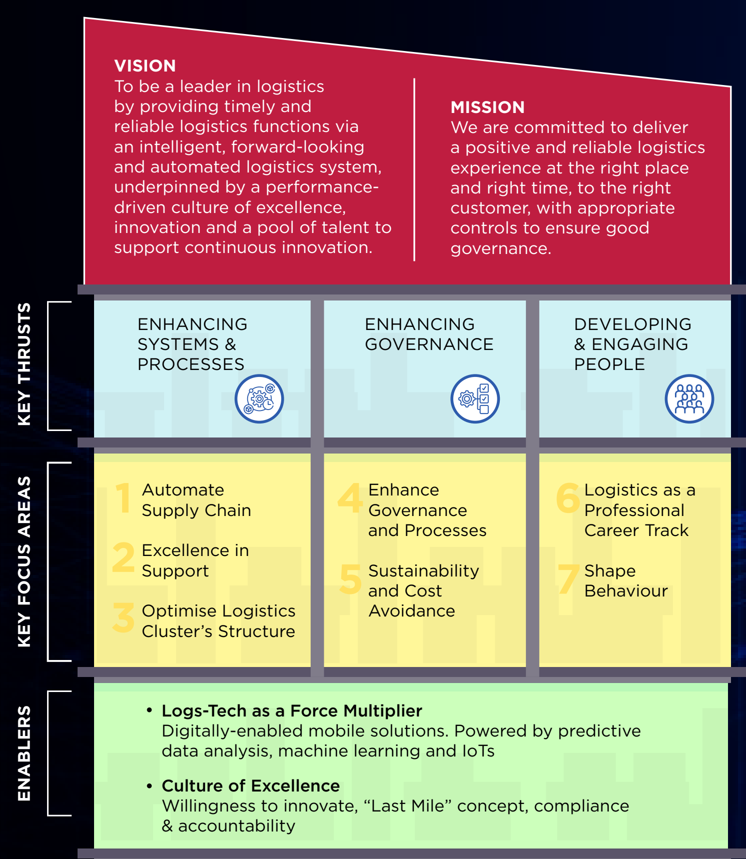
The first layer of logistics support for any incident would be from the responding station's own equipment which is available in their appliances. These items would be available at the onset of the incident when SCDF arrives at the location. Should the incident escalate, the CSH HQ would be activated to provide the required logistics and admin support in the form of a Direct Support Area. If the severity of the incident further escalates to a Civil Emergency,[1] HQ Logistics Department would be activated to oversee the entire logistics support across the nation.

[1] A Civil Emergency is defined as a sudden incident involving large-scale loss of lives and damage to property. It is a major incident with potential to escalate in scale and can have grave national, diplomatic or political implications. Such incidents will require a multi-agency response to manage the entire spectrum of post-incident events.

Level of Incident	Level of Turnout	Level of Command	Level of Logs Support	Logs TE Support	
Initial Turnout	Basic Task Force	Comd, Fire Station	Responding appliances are self-sufficient. No forward deployment of logs.	Depending on the type of fire call, the BTF for the incident is assigned by Ops Centre. The level of logs support would be from the Table of Equipment (TE) list for the appliances dispatched for the incident.	CSH in-situ
Enhanced Turnout	Enhanced Task Force	Div Comd	Direct Support Area (DSA)	Upon confirmation of an incident for escalation by the Commander Fire Station, an incident will be upgraded for the ETF to provide additional resources in an incident. The DSA would be activated and the in-situ team would provide additional logistics resources to support the operations.	CSH HQ
Ops Civil Emergency	Civil Emergency, Executive Group Activated	Commissioner	- CP/TACT HQ Logs Cell - Mobile SS/ Tech Teams - Direct Support Area	When Ops CE is declared, Logs department would be activated to assist to provide operational equipment stored for Ops usage. A pre-defined list of available equipment which is specially set aside for such contingencies would be activated and be deployed to support ground needs.	HQ Logs

LOGISTICS MANAGEMENT TRANSFORMATION

Logistics management is a highly complex enterprise system dealing with, among other things, people, equipment and transportation. While the logistics systems and processes in SCDF work well and are well-oiled, there is a need to chart out the new phase of logistics transformation. Consequently, SCDF embarked on a holistic and ambitious review of its logistical functions. Recognising that logistics is an integral part of operations creates the opportunity to develop logistics management as a "Strategic Differentiator". SCDF has identified various initiatives that will transform logistics management in SCDF.



Intelligent Supply Chain

Supply chain management in SCDF will be automated by leveraging data-driven decision-making processes, while addressing risks via in-built control measures. This ensures the availability of critical supplies and equipment by removing human intervention and lapses, whenever possible. As data is critical, SCDF will leverage the data in a central system as the single source of truth to uncover insights, relationships, root causes and trends across all logistical functions. Future developments will also leverage data captured within this central system.

Upstream, there will be certainty and continuity in the provision of equipment, supplies, and services via the use of a ***Forecasting Model*** which standardises and automates demand forecasting. Downstream, resupply will be automated via a ***Push Inventory Management System to Unmanned Stores*** across SCDF. SCDF is currently running a trial on the operation of an Unmanned Medical Store at Punggol Fire Station. The Unmanned Medical Store reduces the element of human errors in accounting and time delays in stock replenishment as stock holdings would be immediately updated once items are drawn. The Push Inventory Management System would automatically kick in to have items delivered to the stores once the inventory falls below a predefined value.

Figure 1: Unmanned Medical Store

Excellence in Operations and Maintenance

To allow SCDF to perform its functions effectively and efficiently, three key areas are illustrated below:

a. Intelligent Logistics Support during Operations

Live statuses on mission-critical logistics information help commanders better manage incidents and resources. The aim is to integrate logistics information with eStaging/eResource[2] via Internet of Things (IoT) sensors. This provides critical status of vehicles and equipment readily to ground commanders to enhance situational awareness and decision-making.

[2] The eStaging modernises and digitalises the way SCDF operates in a big-scale incident where an on-site command point is required. Current Concept of Operations for the staging would be through the manual use of a board and markers. The new eStaging would instead focus on the use of tablets and a new integrated system which leverages on IoT to support operations. The eResource would provide a seamless integration of SCDF's emergency appliances equipment manifest to a central system during an incident. This would enable the incident commander to better gauge the amount of resources and equipment which are currently on the ground.

b. Reducing Breakdowns via Preventive Maintenance with IoT Vehicle Sensors

Availability of fleet and equipment is critical to operations. When equipment and vehicles are not maintained properly, operation readiness will reduce, while maintenance costs will increase. The installation of IoT sensors on our appliances will allow "live" monitoring via a Fleet Operations Dashboard, and leverage data analytics capabilities to identify potential fault for preventive maintenance before it occurs.

c. Shaping Drivers' Behaviours and Enhancement of Safety Vehicle Sensors

Driving safety is critical to SCDF operations. SCDF has unveiled the Emergency Response Driving Simulators at the Digital Learning Lab in the Civil Defence Academy. The simulators provide our responders with an opportunity to practise emergency response driving in a safe virtual environment. Data analytics is also used to provide insights to facilitate targeted or corrective training.

A comprehensive ***"Driver Profile"*** incorporating training data and daily driving data will be developed to shape driver behaviours. This "Driver Profile" will be made available to unit commanders to facilitate the tracking of risky driving habits. Good drivers will also be identified as role models to others to instil a "safe driving" mindset.

All administrative and emergency vehicles will continue to be enhanced with safety features such as pre-collision warning/braking, auto-braking and driver fatigue detectors to reduce the frequency and severity of accidents.

Figure 2: Driving Simulator

Figure 3: 360 Degree Camera Installed to Enhance Safety

<u>Enhancing Governance and Processes</u>

Governance is critical in ensuring compliance with government-wide rules and regulations, and in ensuring that ground personnel receive right and timely logistics support. Consequently, SCDF exercises fiscal stewardship and is committed to ethical, efficient, and responsible financial decision-making and usage of organisation resources. This includes the conduct of cost reduction exercises to ensure that funds allocated are used prudently.

Harnessing technology as a force multiplier helps minimise human errors and automatically surfaces red flags via built-in controls for immediate actions. In this regard, SCDF has developed a set of ***Actionable Dashboards*** that will automate the tracking and governance of various key areas of concern. The actionable dashboards will recommend the right course of action to officers by automating optimal processes and considerations. SCDF will also leverage data for greater ***governance in fleet management***. The new system will automate the verification process to determine whether the driver and vehicle commander are authorised to undertake the trip. Algorithms to analyse the trip information, together with data from other sources, will surface abnormal trips to supervisors for immediate investigation.

A ***Smart Workplace App*** is also being developed to automate and replace the laborious monitoring and documentation processes. This app will capture the work done by vendors and document the checks and authorisation given by SCDF officers, allowing for a single source of truth during compliance audits. An automated matching service (with a reminder function) will ensure that work is scheduled as per contractual requirements and that work will always be completed via automated verification of work to be done vis-à-vis actual work done.

Figure 4: Actionable Dashboard on Tableau

Sustainability

SCDF aims to be a global leader in sustainable development amongst the Fire, Rescue and Emergency Medical Services (EMS) fraternity. Given the increased focus on sustainability following the announcement of the Singapore Green Plan 2030, there is a need for SCDF to consider the likely sustainability impact, minimise any negative impacts as far as possible, maximise the opportunities, and play a greater role. SCDF has initiated our effort in the sustainability conversation and will meet the sustainability targets in carbon abatement and resource efficiency under GreenGov.SG. Beyond the GreenGov initiatives, SCDF will leverage the Environment, Social and Governance (ESG) framework to drive sustainability in SCDF. SCDF also actively explores how it could recycle its used equipment and to give new life to items which are no longer fit for operational use. SCDF has previously done two donations of its old hoses and would be exploring more collaborative opportunities for its sustainability efforts.

SCDF has adopted and will continue to explore innovations in green firefighting, e.g. use of fire blankets to fight car fires. The usage of the fire blanket has shown to be effective in mitigating car fires and is contrary to the existing firefighting medium of using large volumes of water to extinguish a fire. We will also be replacing the current combustion engine vehicles to using electric vehicles for emergency responses, commencing with the electric fire engine and emergency ambulance. Sustainable solutions will be implemented in the fire stations and the Civil Defence Academy as "Living Laboratories". Finally, we will focus on building up the right culture by seeding various initiatives, with the aim of promoting a ground-up sustainability movement within SCDF.

Figure 5: SCDF Efforts in Sustainability

Talent Management

To enable and sustain logistics transformation moving forward, there is a need to focus on career development and ensure that a constant cadre of competent and committed logistics officers is equipped with the necessary competency to continue to push the frontiers of logistics. It will also attract the right talents to take up logistics posts.

Consequently, a Logistics Competency Framework has been introduced. The framework identifies the ***professional pathways, attachments and sponsorships*** necessary to groom SCDF officers into bona fide logisticians. This includes opportunities to hold various leadership appointments within SCDF, cross-departmental postings to logistics-related posts, and attachments to commercial logistics entities.

CONCLUSION

SCDF has actualised numerous transformation initiatives and remains committed to modernising logistics capabilities and developing our staff to remain abreast of operational challenges. This will allow the flexibility to continue to explore new initiatives and to constantly enhance its service delivery to achieve organisational excellence and to support the Force's Transformation Vision.

ENHANCING FIRE SAFETY STANDARDS AND CAPABILITIES THROUGH THE ESTABLISHMENT OF A FIRE RESEARCH CENTRE

LTC Tong Hong Haey
Senior Assistant Director (Industrial & Institution Design)
Fire Safety Department

MAJ Ho Sze Sien
Senior Consultant
Fire Safety Department

MAJ Soh Seok Yuen
Senior Consultant
Fire Safety Department

HTX Eugenia Teh
Engineer
Fire Safety Department

EDITORIAL PREVIEW

The Fire Research Centre (FRC) will enhance Singapore Civil Defence Force's (SCDF) capabilities by deepening expertise and knowledge in fire science & research and set new benchmarks in evidence-based fire safety standards. The state-of-the-art research facility enables the facilitation of research activities involving fire protection engineering, fire modelling, code validation, fire investigation and firefighting methodologies by enabling users to conduct real-scale fire experiments to evaluate the severity of fire or effectiveness of certain fire safety or extinguishment measures. This article will delve into the key equipment and capabilities, its operating structure as well as the possible test applications that can be carried out in the FRC.

INTRODUCTION

To step up fire research activities in the Singapore Civil Defence Force (SCDF), a Fire Research Centre (FRC) will be set up within the compound of the Civil Defence Academy (CDA). The FRC comprises a 10 MW calorimeter housed within a three-storey facility that is 30 m long, 17 m wide and 17 m high.

The calorimeter has a circular canopy exhaust hood that is 10 m in diameter and can be lowered to the floor, or retracted up to 8 m above floor level, in order to accommodate burning combustibles or structures that are three storeys high. The FRC facility is currently under construction and is expected to be ready in mid-2023. Figure 1 illustrates how the FRC will look like when it is completed.

Figure 1: Illustration of the Fire Research Centre facility and its capabilities

KEY EQUIPMENT AND CAPABILITIES

The large-scale 10 MW calorimeter uses the exhaust hood to capture fire effluents from the burning objects underneath the hood. Sensors and probes are installed after the hood to measure the types and amounts of fire effluents (such as quantities of carbon monoxide, carbon dioxide, smoke, gas temperature, gas composition and flow rate, etc) passing through the calorimeter upon combustion. These measurements enable the quantification of Heat Release Rates (HRR) arising from the burning materials, using the oxygen consumption calorimetry method.[1] HRR is an important parameter that enables the fire severity for different types of combustible materials to be evaluated. The HRR can be described as the amount of heat released by the combustion process as a function of time, normally measured in Watts (W), kiloWatts (kW), or MegaWatts (MW). It provides an assessment of the hazardous nature of the fire and is also related to how much toxic gases, smoke and other types of fire effluents are generated as the fire progresses.

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[1] The oxygen consumption calorimetry method is based upon the constancy of heat released per unit oxygen consumed. It requires the collection of all fire effluent in the exhaust, measurement of the exhaust system flow rate, and oxygen concentration in the exhaust.

As the fire effluents can be harmful to the environment, the calorimeter is also integrated with a wet scrubber system[2] to process and clean these fire gases and smoke generated from the fire before they are discharged into the environment. The exhaust gases and substances will also be cooled before they enter a dust collection system so as to reduce the thermal loads on the dust collection system. During the combustion process, the operational status of all the measurement and scrubber equipment will be monitored in an enclosed Control Room adjacent to the burning area. The overall specification of the scrubber is also designed to meet the standards required by the National Environment Agency (NEA). Figure 2 illustrates the scrubber system and dust collection system installed beside the main FRC building.

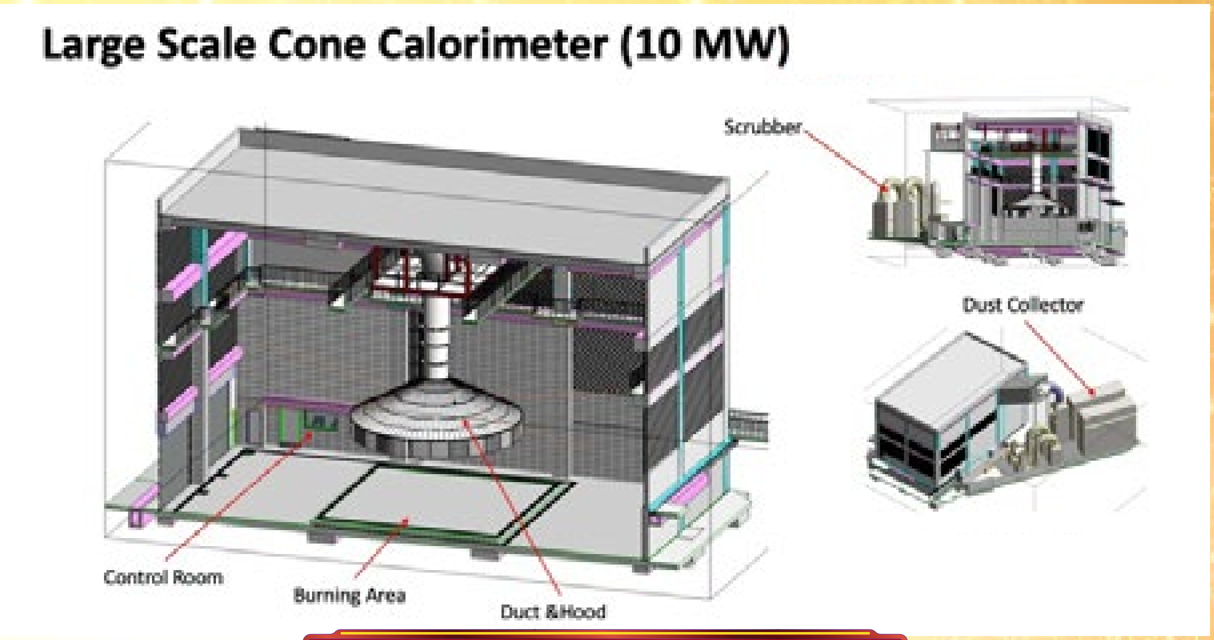


Figure 2: Scrubber and dust collector

In addition to the calorimeter, the facility has independent measurement equipment such as data loggers, thermocouples and heat flux sensors. The FRC also comprises a 5-tonne overhead crane within the premises that is intended to facilitate the easy movement of large bulky items such as large wall or ceiling panels across the FRC. This allows for easy erection and dismantling of customised burn rooms of various sizes. In addition, the FRC features portable video cameras to enable video recording of the burning process. The FRC will also be equipped with thermal imaging video cameras which would allow users to observe temperature changes of burning surfaces during the burning process.

OPERATING THE FIRE RESEARCH CENTRE

The FRC will be operated by officers from the SCDF Fire Safety Department (FSD), CDA, as well as the Protective Security and Safety Centre of Expertise (PSS CoE) of the Home Team Science & Technology Agency (HTX). SCDF officers deal with fire safety regulations and training matters on a day-to-day basis. They will be able to appreciate fire safety issues and concerns for the purpose of fire research and development to improve fire safety outcomes. Officers from the HTX possess fire engineering knowledge and can provide technical advice on calorimeter operations as well as fire testing methodologies and parameters. They are also competent in fire simulation and modelling, and will be able to easily compare fire test results with fire simulation outcomes. Officers from CDA will be involved in the physical maintenance of the FRC and its associated equipment.

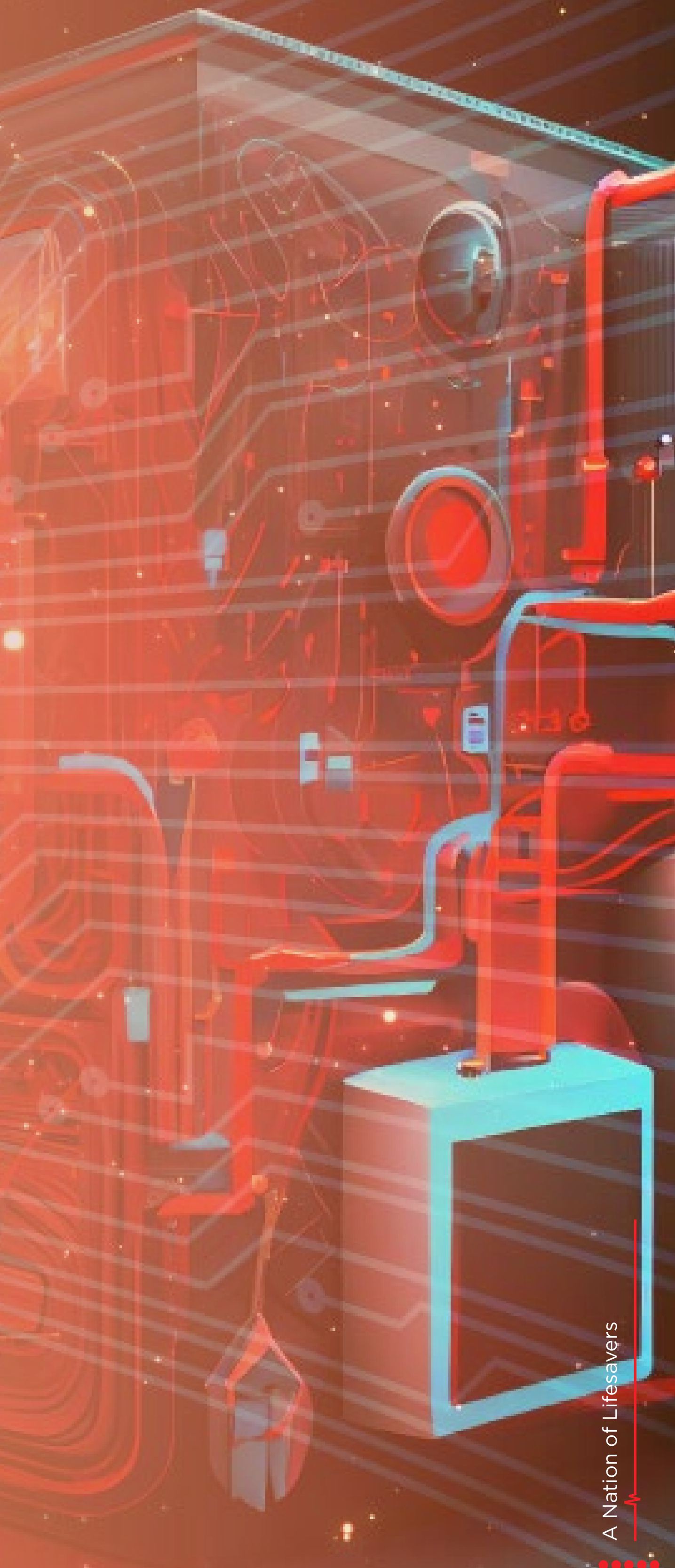
[2] A wet scrubber is an air pollution control device which uses a liquid to remove contaminants from a gas stream. The removal process is achieved by bringing the gas stream into contact with the scrubbing liquid, which facilitates mass transfer of the contaminants into the liquid.

POSSIBLE FIRE TEST PROJECTS THAT CAN BE CARRIED OUT IN THE FIRE RESEARCH CENTRE

Some of the possible fire tests that can be conducted in the facility include testing of new construction materials or renewable energy products (such as photo-voltaic panels, electric vehicles, large batteries, etc.) to support environmental sustainability objectives. Electric vehicles are gaining popularity in Singapore. Carrying out fire testing of such vehicles enables various stakeholders to understand and appreciate the fire risks that come with these innovations. This will also facilitate the development of appropriate mitigation strategies to address those fire risks.

Apart from testing new construction materials, the FRC can also be used to evaluate the effectiveness of new fire extinguishing mediums. Instead of using traditional fire extinguishing mediums such as water, foam, or dry powder, there are newer extinguishing mediums that have been publicised to be equally effective against common combustibles, or even claim to be effective on new technologies or equipment such as battery storages or electric vehicles. In theory, some of these new extinguishing mediums work by improving their ability to absorb heat or remove air from the combustion process, thereby reducing one or more of the elements necessary for combustion to take place. The amount of extinguishing medium required to put out a fire also appears to be much lesser compared to the amount of water or foam required to put out a fire of similar size. Using the FRC and its various measurement tools, the effectiveness of new types of extinguishing medium can be certainly evaluated in an appropriate manner.

Overall, such research projects can contribute to the fire safety community through journal publications of fire research findings. Such sharing of fire safety knowledge will improve the fire safety of these new products, which will ultimately benefit fire safety regulators, industries and even tertiary research institutions. The next section describes an example where the FRC can help improve fire safety designs.



Vertical Fire Spread Test

With a fire test facility of this size, structural designs of up to three storeys can also be tested. A sample of such a structure is shown in Figure 3. In order to reduce instances of vertical fire spread from a lower residential room to an upper residential room via its window openings, the Fire Code 2018[4] stipulates design requirements for horizontal projections and vertical wall dimensions along the external façade of residential buildings. To validate these code requirements, as well as to allow for alternative designs to meet the design objectives, various permutations of the horizontal projections as well as wall dimensions can be installed inside the FRC under the hood. Fires can then be set up in the lowest level, and upper spaces can then be evaluated for the presence or absence of vertical fire spread based on the respective design permutations. The fire size measured during the burning process can also be used as a parameter for subsequent fire modelling activities so that a realistic design fire size can be adopted for modelling.

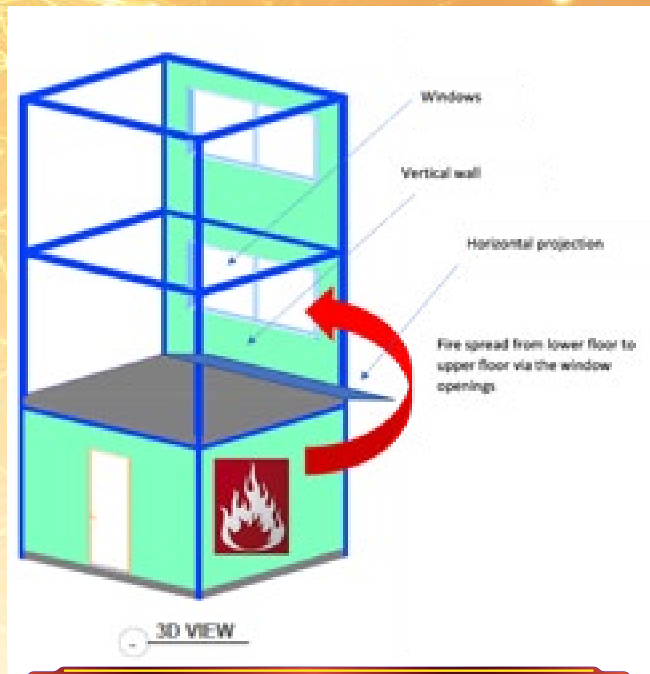


Figure 3: An example of a 3-storey structure to be fitted beneath the calorimeter hood

Use of FRC for Fire Investigation and Forensics Purposes

Apart from the FRC being used as a research facility, it is also useful for fire investigators to leverage the facility for forensic activities such as fire investigation and fire reconstruction scenarios. A reconstruction of an actual residential unit can be set up to mimic the 'before-state' of the fire scene. Fires can then be initiated, and observations on the fire behaviour and development can be made. Assessments on the duration of the fire, smoke travel, pattern of the fire spread and extent of the damage that the fire may have caused can be made and compared against findings from actual fire sites. The resultant fire damage and data obtained from the fire test can also be compared with those obtained from fire modelling. Such studies provide substantial and valuable information to support actual investigation findings, over and above information derived from the fire scene such as closed-circuit television/social media footages and eye-witness/firefighters' accounts of the fire development timeline.

[4] Details of the Fire Code 2018 is available via the following URL, https://www.scdf.gov.sg/firecode2018/firecode2018

CONCLUSION

When the SCDF FRC is operational in mid-2023, SCDF looks forward to partnering with various stakeholders to make use of its experimental findings and knowledge to enhance fire engineering competency, bring about improved and more efficient fire safety building designs, as well as augment fire investigation findings and fire extinguishing capabilities. This new FRC will elevate SCDF's fire research capabilities and enable SCDF to continue to be a leader in our mission to maintain a fire-safe Singapore.

NATIONAL EMERGENCY MEDICAL SERVICES TRAINING CENTRE FIELD TRAINING AREA: REDEFINING PARAMEDIC TRAINING

LTC (Dr) Pflug David
Head, National EMS Training Centre
concurrent Deputy Chief Medical Officer, SCDF
Civil Defence Academy

MAJ Carolyn Low
Course Commander
Civil Defence Academy

EDITORIAL PREVIEW

A professional institution that drives Emergency Medical Services (EMS) training standards and certification needs, the National EMS Training Centre (NETC) is designed and purpose-built to offer a comprehensive training curriculum that imparts professional medical skills, team-based pre-hospital training as well as sophisticated scenario-based training that is aimed to emulate the complete pre-hospital care procedures and processes. NETC will leverage state-of-the-art Mixed Reality (MR) technologies to simulate realistic scenarios for our paramedics and Emergency Medical Technicians (EMT) to conduct EMS training in a safe environment.

INTRODUCTION

The National Emergency Medical Services Training Centre (NETC) Field Training Area (FTA) was an idea spanning years of planning. The dream was to build a state-of-the-art simulation centre to enhance paramedic training realism. This would replicate onsite medical management in as close an environment as possible through simulations. Then Coronavirus Disease 2019 (COVID-19) came along and challenged all our preconceived notions of what our operational and training environment should be.

The challenges faced throughout COVID-19 served to crystallise the NETC FTA Training Concept to focus on several key needs:

a. Simulation Training: From Onsite to End-to-End

b. Single Man Competency Training: From Supervised to Self-Directed, Asynchronous and Decentralised

c. Team-Based Training: Building Teams, Creating Interoperability

d. Way Ahead: From Innovation to Research

<u>Simulation Training: From Onsite to End-to-End</u>

Medical accreditation, from paramedics to nurses to physicians, is aimed at assessing one's ability to treat patients. Historically, the emphasis has been on patient assessment and appropriate administration of medical interventions onsite by a single individual. Previous simulation systems and centres globally reflect this, including within the SCDF where our current simulation rooms are built for single man skills testing. This created a system of training and accreditation matching each level (emergency medical technicians, paramedics and advanced paramedics), where robust assessments look at individual capabilities to manage patients onsite.

With the maturity of the SCDF Emergency Medical Service and Pre-hospital Emergency Care, came the awareness that this was only a subset within the much larger domain of Pre-hospital Emergency Care. More importantly, it was recognised that pre-hospital care was a critical link in the chain of medical management all the way to hospital discharge, often making a significant impact on patient survival. With the prior focus on onsite management, additional domains of what constituted this environment were explored. These domains may be divided simply into Response to Call, Patient to Ambulance, Ambulance Care and Handover to replicate our Operational Environment.

The new NETC FTA is designed with this purpose in mind. The first level of the FTA is divided into four zones:

1. The Concept Classroom is where scenario participants are briefed and activated to assess their initial response to call. It also allows for observers to view the scenario play in real time through a mix of direct visual and television displays.
2. The Concept Room allows for assessment of onsite patient management till transfer to ambulance. It simulates different environments ranging from residential, commercial to industrial. With further augmentation through Immersive Projection systems and audio systems, simulation realism is greatly enhanced to improve on training.
3. The Ambulance Simulator is where ambulance care en route to the hospital is trained and assessed. It is designed to replicate the latest Gen 7 ambulance but modular to allow for replication of future generations of ambulances.
4. The Resuscitation Room replicates the hospitals' Emergency Department environment, allowing for the practice and assessment of Clinical Handover of patients as well as Emergency Department team management of patients.

This is enabled by an integrated system of audio-visual sensors and coordinated by a central hub located on the mezzanine floor which overlooks the Concept Rooms. From the mezzanine floor, a trainer can control the scenario from end to end and enable the display of the scenario play in the Concept Classrooms for observer learning.

<u>Single Man Competency Training: From Supervised to Self-Directed, Asynchronous and Decentralised</u>

Pre-hospital Emergency Care is still built on the foundation of clinical core skills competencies. In the past, candidates were trained and assessed onsite to demonstrate proficiency in these skills using simulators. This was done by instructors standing over their shoulders to ensure each step is complied with meticulously. What this translated to was that annually paramedics across Singapore would have to book sessions with NETC to schedule their certification tests. These sessions would be synchronous and centralised at NETC. Prior to these tests, they depended on their skills accumulation with real patients or ad hoc training sessions which were self-arranged. COVID-19 changed how we perceived training and certification, providing us with a stretch goal that both training and certification should aim to be asynchronous and decentralised.

The NETC FTA Level 2 consists of the Skills Lab, designed to be a test bed for the future of training and certification. The Skills Lab is composed of multiple booths equipped with individual task simulators. It is designed to allow for individuals to sign in, and utilise the simulators aided by a self-directed lesson plan to train in each core skill competency. This is augmented by sensor systems to allow instructors to audit performances and built-in integration of the simulator internal sensors to assess skill proficiency.

As this process is refined, the long-term aim is to be able to replicate these booths in the wider SCDF. This would allow paramedics to conduct individual skills proficiency training in an asynchronous and decentralised manner. As it matures and technology advances, the dream is to eventually allow for AI-supported certification of these individual core skill proficiencies.

<u>Team-Based Training: Building Teams, Creating Interoperability</u>

Both these systems play a role in setting the foundation of Pre-hospital Emergency Care training for all SCDF trainee populations (Full-time National Servicemen (NSF), Regulars, and Operationally Ready National Service (ORNS) men). Additionally, they allow trainees to have self-directed equipping of core skills combined with increased emphasis on team-based end-to-end simulation training. This serves to optimise team-based performance, with the analogy commonly used by the Formula 1 (F1) pit team. In F1 pit teams, each person is familiar with their individual roles, and training involves integration into team-based performance. This is a vast difference from the historical individual skills emphasis.

But this is still not enough. As hinted at earlier, Emergency Medical Services (EMS) does not operate in isolation. Other pre-hospital care collaborators include hospitals' Emergency Departments and the Fire Rescue Service. Within the NETC FTA, there is a Resuscitation Room which is built to replicate hospitals' Emergency Department Priority 1 Resuscitation Areas. These are areas where the in-hospital medical teams receive Priority 1 patients from the Pre-hospital Care teams and take over management. This area not only allows for the Pre-hospital Care teams to practise their handover but also creates scope for interoperability training between the Pre-hospital and Emergency Care teams.

Way Ahead: From Innovation to Research

The area of simulation medical training is still immature; the impact of all these systems is challenging to conclusively determine. The NETC FTA is also meant to be a test bed for evolving medical simulation technologies. One of the areas of immediate interest as highlighted earlier is in AI-driven asynchronous and decentralised training and certification. We hope to be able to develop the systems and incorporate technologies into achieving that goal in the near future.

One other area we are already exploring is in the field of Mixed Reality training. Utilising technology, we can overlay environments within the Concept Rooms to replicate low frequency but high criticality scenarios. An example of this is a mass casualty situation. Using technology to enhance training realism serves to mitigate the impact of a real-life situation because trainees then become more familiar with the challenges involved and streamline focus on the tasks required. With this, we hope to be able to mentally prepare them for this contingency and equip them with the skills needed to help patients survive in these times of crisis.

In addition, NETC hopes to add to the body of knowledge in medical simulation research, validating these systems and the impact on improving patient outcomes. Thus, it can grow to become a leader in pre-hospital care nationally and beyond.

FUTURE STATE

The envisioned NETC FTA is designed to be a state-of-the-art Pre-hospital Emergency Care Training Centre intended to replicate our operational environment end-to-end. It builds in future proofing to bridge towards self-directed training and certification that is both decentralised and asynchronous. It not only allows for training across all SCDF trainee populations (NSF, Regulars and ORNSmen) but also interoperability training with all pre-hospital care collaborators including Fire Rescue Services and hospital-based teams. Scope is created for Innovation in Simulation Technology, and Research in Pre-hospital Care Optimisation and Paramedic Training.

The NETC FTA is the crystallisation of the dreams of generations of EMS personnel. Standing on their shoulders has put SCDF at the forefront of EMS training for generations to come.

DEVELOPMENT OF AN EVIDENCE-BASED PROFICIENCY TEST FOR FIREFIGHTERS

LTC Hasan Kuddoos
Commander
Marina Bay Fire Station

CPT Mohamed Noor Hafiz Bin Abdul Halim
Senior Responder Performance & Accelerated Recovery Officer
Civil Defence Academy

Leong Hin Fong
Senior Scientist, Human Performance, Interaction & Teaming
Human Factors & Simulation Centre of Expertise
Home Team Science & Technology Agency

Lowell Chong
Senior Scientist, Human Performance, Interaction & Teaming
Human Factors & Simulation Centre of Expertise
Home Team Science & Technology Agency

EDITORIAL PREVIEW

The Singapore Civil Defence Force (SCDF) introduced the Breathing Apparatus Proficiency Test (BAPT) in 1999 to assess the competency of SCDF firefighters in breathing apparatus (BA) fitness and proficiency. The BAPT is designed to assimilate the physical rigours of operating a self-contained breathing apparatus (SCBA) for the working duration of a fully charged 9-litre SCBA set. The existing BAPT regime comprises a sequence of six test stations aimed at assessing cardio-respiratory fitness, strength, psychomotor coordination and endurance of test participants.

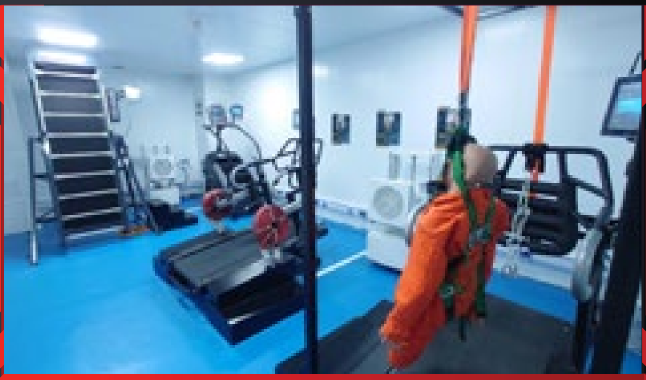


Figure 1: New BAPT static stations housed in the Heat Acclimatisation and Thermoregulation (HEAT) lab

In line with SCDF's transformation efforts to adopt evidence-based practices, the existing BAPT regime was reviewed, and improvements were made to the test stations and its parameters to incorporate ops task relevance and performance optimisation, all while enhancing safety through the monitoring of firefighters' heart rate (HR) during the conduct of BAPT.

This article shares the background of the review, its methodologies, and findings, and discusses the implications of implementing the new BAPT test regime.

INTRODUCTION

Firefighters face a unique challenge of having to wear the self-contained breathing apparatus (SCBA) and turnout clothing (total weight usually at least 25 kg) for protection during firefighting, which imposes additional physiological stress (Lesniak et al., 2019; Louhevaara et al., 1985). The nature of the job imposes high physical demands in terms of aerobic fitness, anaerobic capacity, muscular strength and muscular endurance on firefighters (Smith, 2011). As such, firefighters must be physically fit in order to cope more effectively with the challenging demands during emergency situations as well as to reduce work-related injuries (Peterson et al., 2008).

Job simulation tests, like the BAPT, comprise physically demanding tasks, which simulates as closely as possible the performance of critical on-the-job tasks. A successful task performance is evaluated relative to time taken to complete the task by safe and efficient incumbent personnel. In addition, it was recommended that a good test should distinguish between those who can and cannot do the job, regardless of age, gender or experience (von Heimburg et al., 2013).

While the former BAPT regime has served SCDF well over the past two decades, it was timely that BAPT underwent a comprehensive review to remain current through research efforts with firefighters, for firefighters.

COMPREHENSIVE REVIEW OF BAPT REGIME

Past BAPT Study

In a previous research study, the former BAPT regime was evaluated to determine the suitability and effectiveness of test batteries. The two-year study analysed the BAPT along with various parameters ranging from operational task relevance (of the test stations) to physiological responses and vital sign measurements of the test subjects when undergoing the BAPT test stations.

Eighty male SCDF firefighters participated in the study, where their maximal oxygen uptake (VO_2max) and maximum heart rate (HRmax) were documented as indicative parameters to determine the relative physiological responses.

Table 1: Summary of findings

Current Test Station	Task Relevance	Within HR & VO_2 Parameter	
		HR	VO_2
Endless Ladder	✓	92.9%	90.6%
Running Belt Ergometer (Treadmill)	✓	68.5%	53.5%
Impact Machine	✗	91.8%	62.6%
Bicycle Ergometer	✗	88.3%	67.2%
BA Maze	✓	99.5%	67.2%

Analysis of the trial results revealed that while most of the test stations displayed positive outcomes in terms of eliciting the desired physiological responses (i.e. falling within accepted ranges), the running belt ergometer (treadmill) reflected sub-optimal scores while the endless ladder exceeded the operational working limit of 60-80% of VO_2max. Refer to **Table 1, Figure 2 and Figure 3** for details.

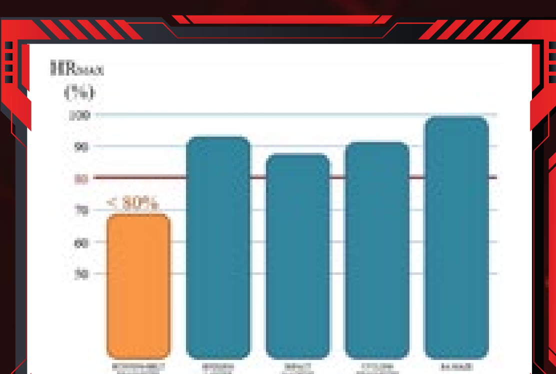


Figure 2: Mean HR expressed as % of HRmax of five test stations (excluding BA donning)

Figure 3: Mean VO_2 expressed as % of VO_2max of five test stations (excluding BA donning)

Primary Study

Adopting a methodology similar to the past study, a follow-up study was conducted where improvements were made to the test stations to better reflect firefighting tasks and, through the monitoring of HR and VO_2, ensure physiological responses elicited were close to actual firefighting operations.

Aim

The first aim of the primary study was to evaluate and ensure that the new BAPT test stations were able to elicit and simulate the physiological demands of our local firefighters in actual firefighting operations. Previous studies have reported that firefighters commonly work between 60 and 85% of their VO_2max and beyond 80% HRmax when performing fire suppression tasks (Morris & Chander, 2018).

The second aim was to establish an objective scoring system for the new BAPT regime. The hypothesis was that there should be necessary minimally required performance standards as they relate to the ability of firefighters completing firefighting tasks as safely as possible.

Methodology

Pilot Trial

Prior to the primary trial, a pilot trial was conducted to determine a suitable set of test stations as well as corresponding baseline standards. The pilot trial, which consists of a sample size of 20 participants, was conducted in ambient temperature. Both HR and estimated VO_2 were measured as indicative parameters to determine firefighters' common physiological responses when put under stress during real operations. The estimation of VO_2max was derived through the participants' 2.4 km run timing (Trinh, 2019) and the correlation between HR and VO_2 (Swain et al., 1998) was computed for individual test stations.

The test requirements were derived from tasks that are commonly performed during operations. Moreover, existing protocols within SCDF were defined as target parameters for participants to complete each test station. Similar to the former BAPT, participants were required to complete each test station within 3 minutes and given a mandatory 2-minute rest in between each test station. **Table 2** shows a summary of the test requirements for the pilot trial.

Table 2: Test requirements for pilot trial

S/N	Test Station	Test Requirement
1	BA Donning	Don full PPE and SCBA within **1 min 15 sec**
2	Hose Carry	Walk **50 m** while carrying **2 x 64 mm** fire hoses
3	Ladder Climb	Ascend **24 m** up the ladder
4	Stairs Climb	Climb **24 m** up the stairs with no additional load
5	Casualty Carry	Perform a backward drag of a casualty weighing approximately **50 kg** over **30 m**
6	BA Maze	Navigate through the BA maze measuring **120 m**

On average, the results showed that all test stations elicited average HR level of above 80% HRmax, with only ladder and stairs climb exceeding 90% HRmax, albeit only for a very short duration (see **Figure 3**).

Figure 3: Typical HR trend during BAPT

Primary Trial

A total of 116 trained firefighters (110 males, 6 females), who are in active frontline duties between the age of 18 and 55 years at the time of the trial, were recruited.[1] Test requirements were similar to those administered for the pilot trial (see **Table 2**).

The trial was conducted over two phases and participants were required to attend two separate sessions. Participants were briefed on the trial objectives and protocol, and informed consent was obtained from participants prior to the commencement of the study. Participants were also instructed to follow the following guidelines before each trial session: (i) not to engage in any vigorous exercise for 24 hours beforehand; (ii) not to eat a large meal at least 3 hours before the tests; (iii) abstain from nicotine use and caffeine for at least 3 hours before the test; and (iv) to reschedule the test if they had fever, an infection or a cold.

Phase 1

- A heart rate monitor (Polar, Finland) was fitted snugly across the participants' chest
- Participants were given sufficient time to perform warm-up activities
- Participants were instructed to don their full firefighting PPE, including the SCBA, face mask and lung demand valve (LDV)
- Resting HR of each participant was recorded after 5 minutes
- BAPT was conducted in the HEAT lab[2] (constant ambient conditions: 28°C, 80% relative humidity)
- Participants were required to attempt each individual static station at prescribed criteria, namely hose carry, ladder climb, casualty carry and stair climb (in random order)
- HR was allowed to return to within 10% of resting HR or after 5 minutes (whichever is earlier) before the next station
- For each station, the highest 30-second average HR recorded was used to calculate the percentage of HRmax achieved. HRmax was determined using estimation (i.e. 220-age)
- Time taken to complete each station was also recorded
- After cessation of tests, participants were instructed to perform cool-down exercises and debriefed

Phase 2

- A heart rate monitor (Polar, Finland) was fitted snugly across the participants' chest
- Participants were given sufficient time to perform warm-up activities
- BAPT was conducted in the HEAT lab (constant ambient conditions: 28°C, 80% relative humidity)
- Participants were instructed to don their full firefighting PPE, including the SCBA, face mask and LDV
- Participants are required to undergo the full BAPT test regime including the BA maze, with 3 minutes to complete each static station (i.e. hose carry, ladder climb, casualty carry and stair climb) and 2-minute rest in between each station
- Time taken for each station and overall completion rate were recorded
- Air pressure on the BA set was recorded
- After cessation of tests, participants were instructed to perform cool-down exercises and debriefed

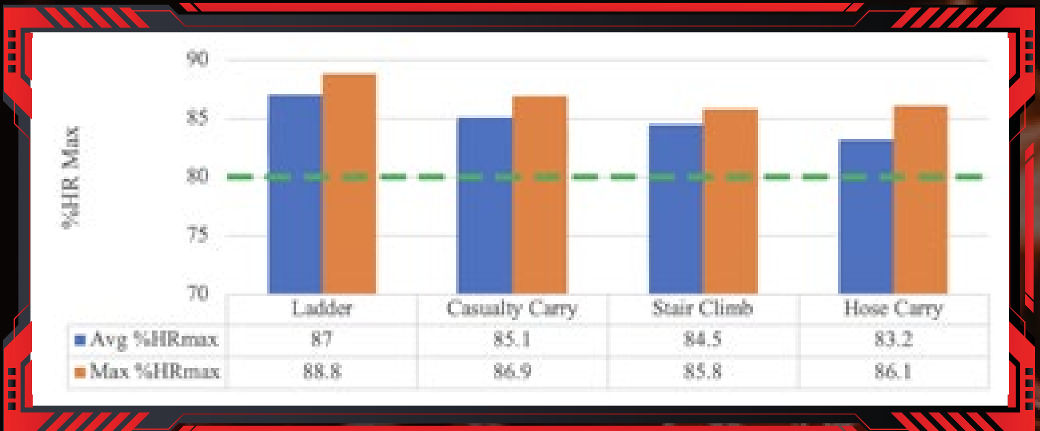
1 Participants include both SCDF conscripts and regulars.

2 Measuring 45sqm, the HEAT Lab allows the simulation of desired climatic conditions with the use of temperature, humidity as well as wind and it can go from -10°C to 80°C

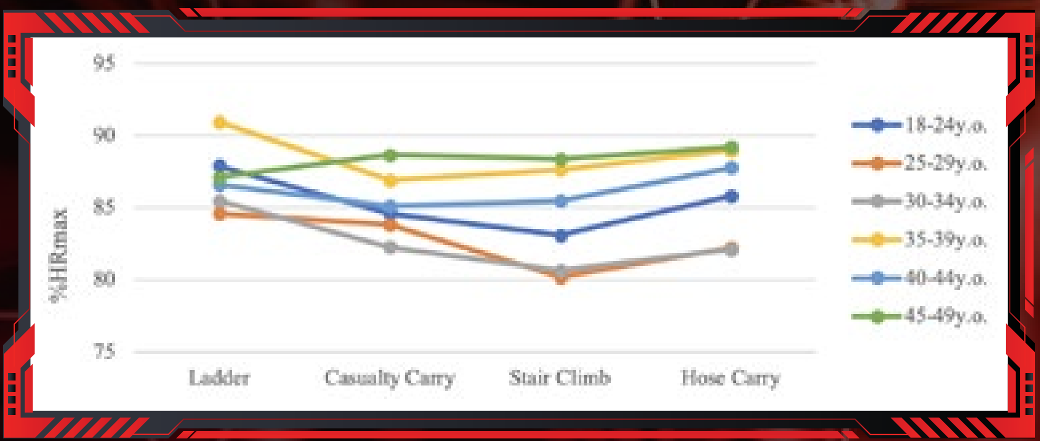
SUMMARY OF FINDINGS

Findings 1 – HRmax

- On average, participants achieved target HR responses of **above 80% HRmax** across all stations

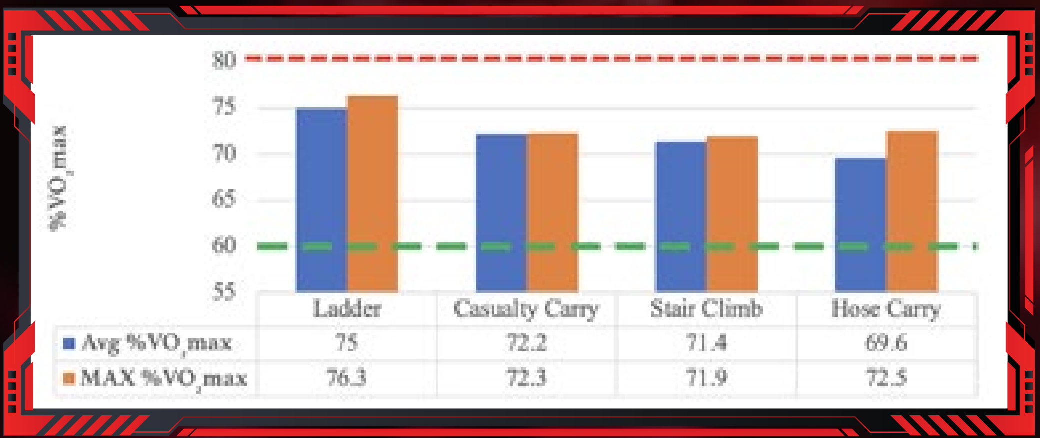


- No significant difference in %HRmax between age groups
- Stations were generally less strenuous for firefighters aged 25–34 years



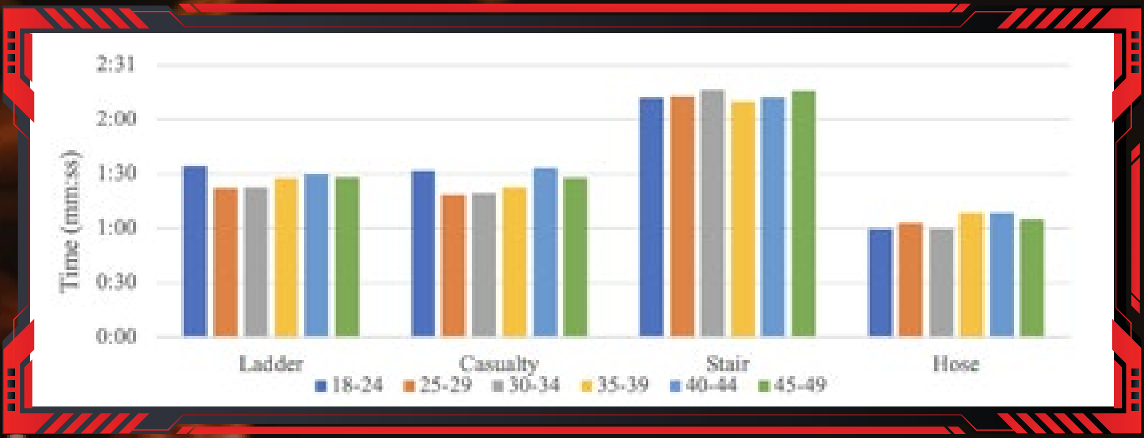
Findings 2 – VO_2max

- On average, participants experienced the target zone of 60-80% VO_2max for all stations

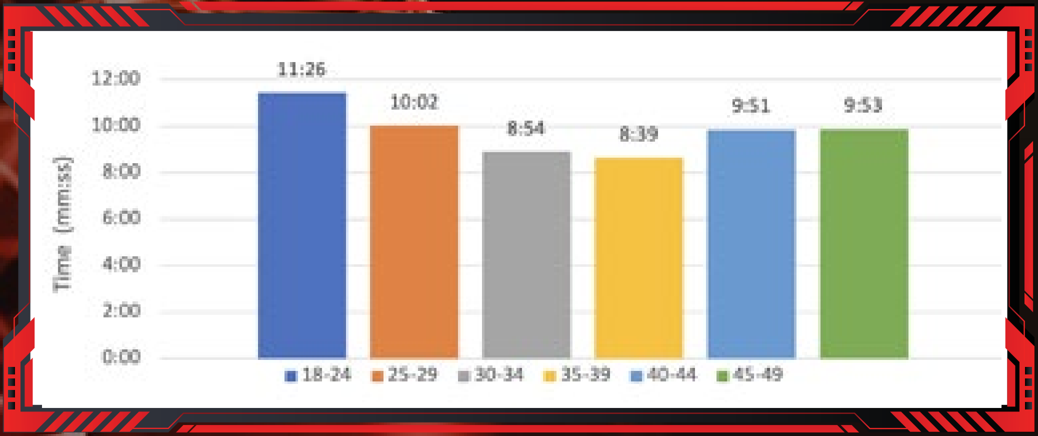


Findings 3 – Time Taken

- Average time taken for each static station was below 2 min 30 sec
- No significant difference in completion time across the age groups

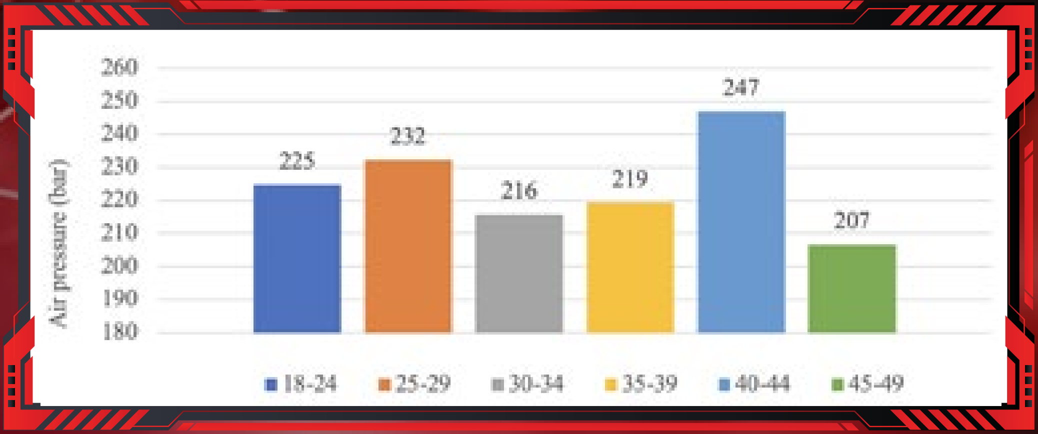


- Average time taken for BA maze was below 12 min across all groups



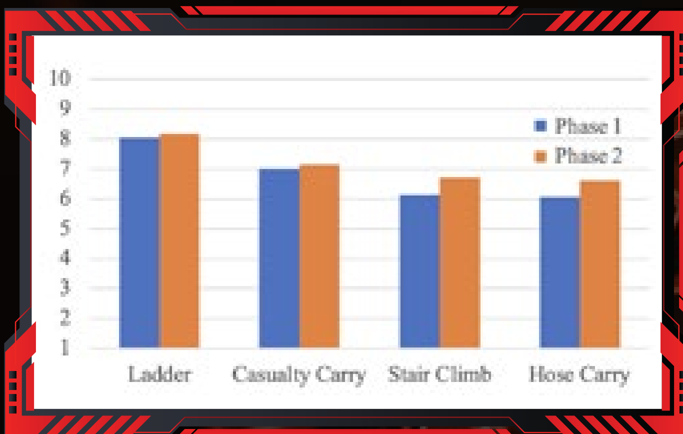
Findings 4 – Air Consumption

- Most firefighters completed the entire BAPT regime with <240bars of air except for the 40 to 44-year-old group
  - 6 out of 11 participants from that age group consumed >240bar



Findings 5 – Perceived Exertion

- On average, the stations were perceived as vigorous activities



RECOMMENDATIONS

From the findings, it was recommended that the new BAPT regime adopt the test requirements administered and scientifically validated through the trial, with a common pass/fail requirement — the physiological responses aligned with the parameters indicated in past literatures. The new BAPT regime is age and gender-neutral, and solely based on one's ability to complete the required fire and rescue tasks since operational circumstances do not differentiate between individuals. Moving forward, data from the BAPT conducted will still be collected over a larger sample for further review.

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THE EVOLUTION OF SCDF'S FIREFIGHTING SUIT – LEVERAGING ON SCIENCE AND TECH TO OPTIMISE PERFORMANCE AND ENHANCE SAFETY

LTC Foo Yiing Kai
Commander
Punggol Fire Station

WO2 Md Farhan Tokaran
Deputy Rota Commander
Punggol Fire Station

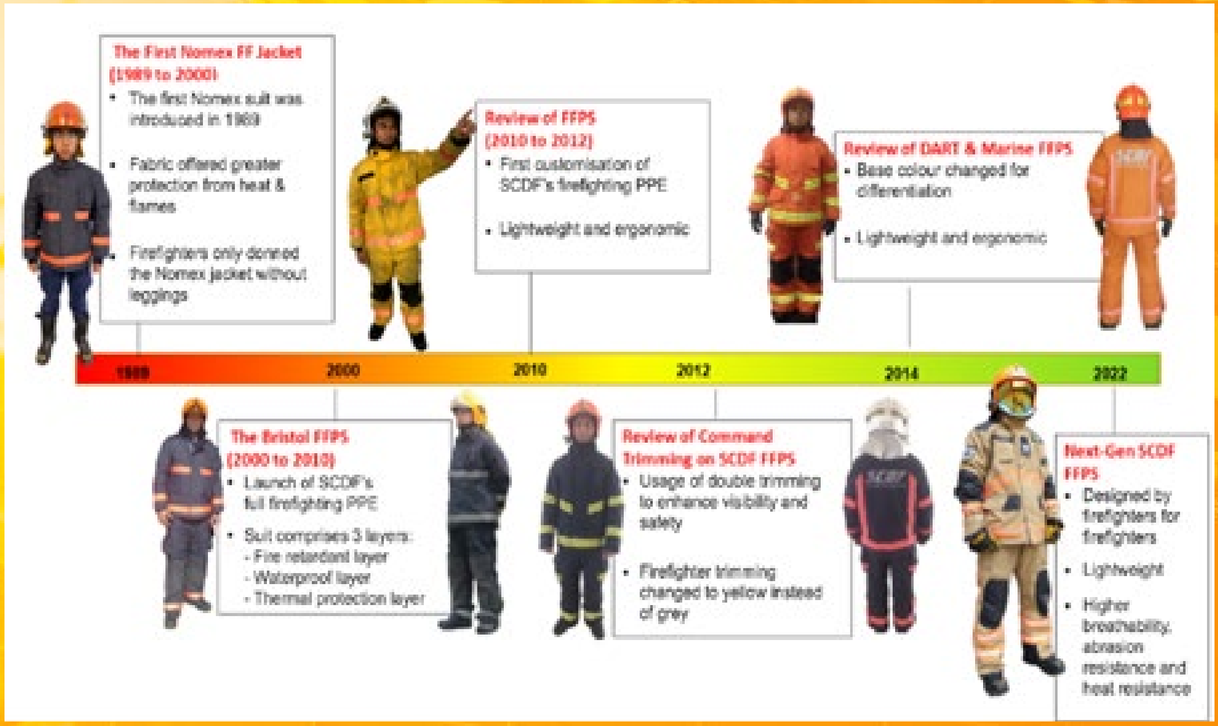
EDITORIAL PREVIEW

Firefighting operations are hazardous and physically demanding. During such operations, firefighters are often exposed to extreme temperature, heavy loads over harsh conditions and prolonged anxiety. These conditions are very taxing to the physical and physiological state of a human being. Firefighters must also be physically fit considering that firefighting operations are very tedious and require high levels of strength and cardiorespiratory fitness. In addition to being physically fit, firefighters need to be properly equipped and protected in order to keep themselves safe in a fire incident. We will explore how SCDF enhanced the firefighting protective suit to better protect our firefighters.

INTRODUCTION

The fact is, as heat loads and toxicity exposure risks increase due to modern synthetic construction, the ways in which fires are fought are changing as well. These shifts, combined with the revolution taking place in firefighter protection technology, have led to new and exciting designs in SCDF's Firefighting Protective Suit (FFPS).

SCDF's FFPS has come a long way in recent years. Our responders rely on the FFPS to protect them from heat, flames, and a variety of other potential hazards, such as hazardous and toxic chemicals. FFPS encompasses both the jacket and pants and anything worn beneath the top layer ensemble. The FFPS has evolved not only with improved materials, technology and cleaning/disinfecting processes but also the evolving role of firefighters in society.



UNDERSTANDING THE FFPS

SCDF firefighters face many fire scenarios within different types of structures, and there is risk of being exposed to hazardous materials such as flammable liquid spills and explosions. All these emergency scenarios require that the FFPS be suitable, comfortable and water-resistant. FFPS must keep moisture away from the firefighter's skin to prevent burns and provide comfort. In addition, the clothing must protect against a variety of hazards including radiant heat, flame exposure, and hazardous materials exposure. The FFPS should fulfil the following requirements:

a. Protection from radiant heat,

b. Minimise the risk of burn injuries and chance of heat exhaustion,

c. Highly breathable and allow sweat evaporation (i.e. permeable to water vapour),

d. Should allow evaporation of 1–2 L of sweat/hr,

e. Should dissipate metabolic heat and maintain a thermal equilibrium and comfort in a wide range of fire intensity, climatic conditions, and duration of work.

For protection and comfort, the FFPS used for structural firefighting usually comprises multiple layers.

In the 1960s, FFPS consisted of simple wool jackets and trousers and sometimes PVC leggings. Wool was chosen back then because of its ability to protect against heat and cold, and its natural water and fire resistance properties. This low-tech solution was still in use up till the early nineties, though of course there were numerous improvements throughout the years.

Since then, the evolution in protective clothing has been increasingly rapid, as we improve our understanding of the risks associated with firefighting and technology improves drastically. Currently, SCDF's FFPS is made from lightweight fire-resistant fabrics, specially designed to block particulate matter while reducing heat stress. The SCDF FFPS today comprises three layers, each serving a function and is necessary, and complies with EN469.

a. External Layer

This is the outermost and therefore most durable part of the suit. It provides protection from heat, abrasions and cuts, and is a barrier against hazardous chemicals or water. The durability and performance of the outer layer's fabric are determined by its composition (the fibre blend), construction and weight. Modern FFPS is made up of a combination of fire-resistant fabrics such as PBI, Nomex, Aramid or Kevlar, which are both strong and lightweight in comparison to previous materials used.

b. Moisture Barrier

This is the middle layer of the ensemble, which is designed to protect against liquids — water, toxic chemicals, and dangerous pathogens. The moisture barrier also plays a crucial role in the breathability and insulation of the entire suit, and therefore, the overall level of comfort and protection for the wearer. Most modern firefighter suits now employ the GORE-TEX Moisture Barrier which achieves 99.9% blocking efficiency when evaluated using the particulate blocking test. The technology is critical to firefighters' safety and well-being.

c. Thermal Barrier

This is the innermost layer of the ensemble which provides insulation whilst minimising heat stress. It also wicks moisture away from the surface of the skin to maintain the wearer's comfort during prolonged use.

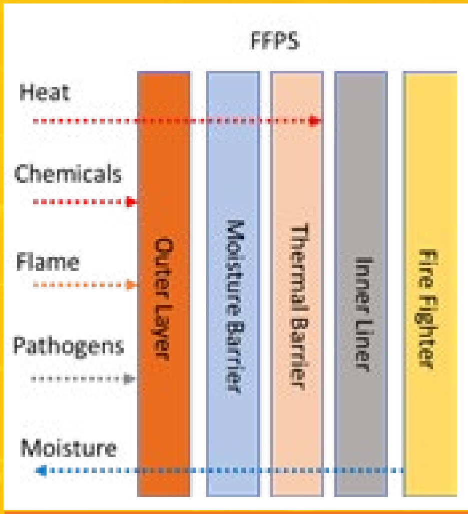


Figure 1: SCDF FFPS Layering System

Keeping in mind various activities like extinguishing fire, rescuing casualty, climbing stairs/ladders, etc. during an operation, the SCDF Next Generation FFPS needs to be designed to perform several functions. It offers a limited degree of protection from thermal radiation, hot gas convection from a fire and direct contact with hot surfaces.

A good FFPS depends on its performance as well as the degree of comfort. However, these two requirements are contradictory and when it comes to heat and flame protection this becomes more obvious. The clothing should protect from flame and prevent the external heat from entering the body. In addition, it should allow the flow of excessive metabolic heat which indicates low thermal resistance and higher water vapour permeability. The essential comfort requirements of FFPS are as discussed.

a. Thermal Comfort

FFPS with suitable combinations of clothing materials and garment structures can facilitate the evaporation of perspiration, hence maintaining thermal balance. When high level of protection is achieved, the physiological comfort of firefighters can be compromised. This in turn reduces work efficiency and the working duration of firefighters. This can be resolved through the selection of advanced materials (both for performance and comfort) and adoption of appropriate FFPS design to help reduce heat stress. The other approach to this problem is controlling the level of exposure or environmental conditions through Standard Operating Procedures (SOP). In both approaches, the thermal load is reduced by shortening the time of exposure and/or changing the ambient conditions. The quantitative assessment of these approaches requires a method that considers the important factors that are relevant to the physiological effect. Changing the environmental conditions is rather difficult, which leaves the scope to design appropriate FFPS with good thermo-physiological comfort properties.

b. Moisture Management

The moisture management properties of a FFPS are significantly affected by the type of material used. Materials with high liquid absorption and wicking properties are generally considered comfortable and can be selected for clothing used for duties involving high activity level such as firefighting. Firefighters face the risk of steam burns due to condensation of evaporated moisture on the skin. The use of a moisture barrier can prevent sweat from soaking the entire garment and keeps the firefighter dry. The microporous structure of the moisture barrier prevents water from moving back towards the skin. It facilitates water vapour (generated from sweat) escaping into the environment and thus reduces steam burns and heat stress.

c. Psychological Comfort

Firefighting in extremely hot conditions can lead to emotional stress for firefighters, which has a significant importance on their health and safety as well as that of the crew and the public. The cognitive performance of firefighters decreases due to environmental conditions and levels of dehydration, in addition to the intensity of the work performed during firefighting. The ability to stay focused in task-relevant information reduces during times of increased stress. Profuse sweating during firefighting can reduce body mass by about 2% which has an impact on mental concentration and working memory. The impact of heat stress and dehydration affects the mental performance of firefighters. The physiological stress, discomfort and psychological aspects (anxiety) can deter their ability during firefighting. As the stress level during firefighting increases, the task-focused thinking reduces. The mental performance declines as the cerebral blood flow is reduced due to heat stress which impacts cognitive performance. Psychological strain can be reduced by the maintenance of proper hydration levels and active body cooling. As the amount of research on psychological stress and its impact is limited, future research should focus on the cognitive function of firefighters. This can be performed in climatic chambers in hot conditions while firefighters perform physical tasks for the typical duration and at the intensities that reflect the energy expended during firefighting. Computer-based cognitive function tests that have ecological validity can be used to evaluate stress levels and their impact.

d. Ergonomic Issues

The use of FFPS has always been an issue when mobility is considered. The mobility and comfort of firefighters should not be drastically reduced while designing the FFPS. Various factors such as the layering systems, type of materials used, sizing and fitting affect mobility. As the number of layers, physical bulk or the overall weight of the FFPS increases, the mobility of the firefighter is reduced.

SCDF NEXT GENERATION FFPS

Better understanding of material science and knowledge of the risks involved in firefighting helps facilitate SCDF in designing its Next Generation FFPS by focusing on the ability to balance heat and physical performance with improved mobility and stress reduction. SCDF has identified 4 key characteristics which are important to the design and selection of materials for the FFPS.

Designed by firefighters for firefighters, SCDF's new FFPS is built to better protect our responders from the extreme heat and harsh environmental conditions that they operate in. The design of the FFPS took into consideration factors such as firefighting conditions, ergonomics of movement, heat stress, anthropometry, and thermo-physiological behavior in addition to protection level. The variables for the final design include the number and combination of layers, material types for each layer and total weight of the FFPS.

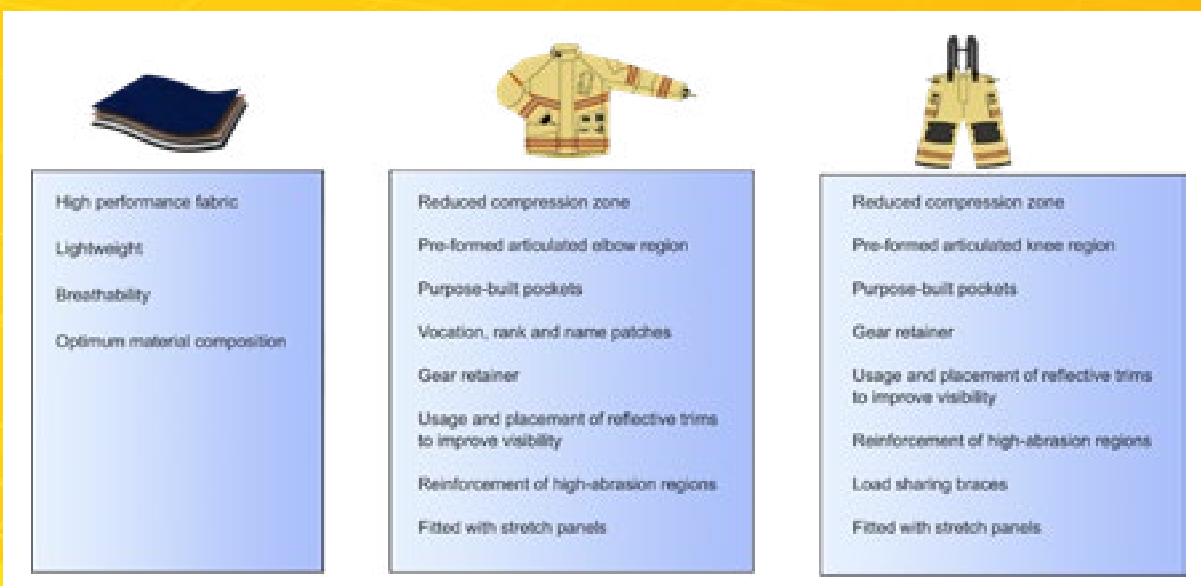


Figure 2: SCDF FFPS Design Requirements

a. <u>SCDF Sizing</u>

A customised FFPS ensures proper fit and, hence, maximum protection and comfort to suit different body dimensions. Furthermore, correct sizing, appropriate fit and ergonomically designed clothing are essential, as a lack of these factors can lead to burn injuries or restriction of movement. For example, a tight-fitting FFPS may prevent a firefighter from moving freely, or it may tear and expose the firefighter to radiant heat.

During the design and sizing phase, SCDF conducted a fitting exercise and took measurements of 200 firefighters and derived an SCDF sizing chart. In addition, the clothing for female firefighters was designed by taking female body features into consideration. Appropriate sizing is important to achieve the desired level of protection. The correct length of jacket sleeves and leggings is essential to provide protection to the wrists and feet. The FFPS has also been tested for the correct fit for the firefighter before actual firefighting.

Consistent sizing practices can develop the correct fit and interface with other safety equipment. As the anthropometric data varies from person to person, designing customised clothing for individuals is essential. The FFPS with correct closures and appropriate coverage provides better thermal protection than close-fitting FFPS in flash fire experiments done using burn manikins.

In addition, the technical developments in 3D scanning have helped SCDF to design the FFPS with correct sizing and fit. It has helped access the air gap distribution in the clothing objectively.

If the clothing is too tight, mobility is limited and excessive load is exerted to muscles and body parts, which in turn can lead to fatigue. When tight and heavy FFPS is worn, the metabolic activity of the body increases, leading to unwanted heat production. Prolonged wearing of the tight FFPS can develop hotspot and, in actual firefighting conditions, the exposure to flame and radiant heat can cause skin burn injuries.

Figure 3: SCDF FFPS Fitting Exercise

b. Ergonomics

A firefighter may not be psychologically comfortable wearing a uniform with improper fit and sizing. Easy donning and doffing, collar design and closure systems, pockets, areas of the elbow, underarm, knee and crotch are some important design aspects to be considered. The underarm and elbow area can be fitted with bellows and gussets to enhance mobility. The design should not hinder the use of other Personal Protective Equipment (PPE) such as helmet, gloves, fire hood, firefighting boots and Self-Contained Breathing Apparatus (SCBA).

Figure 4: SCDF Next Generation FFPS

i. Tapered Rear

Ninety-five per cent of all midbody flex occurs to the front (causing rear body extension only). Since this body extension results in a protection gap between coats and pants in certain body positions, this implies coats can be worn much shorter in front than in the rear. Shortening the non-functional front and keeping the same back length reduces garment weight by 18%-25%, improves ventilation, allows unrestricted upper leg mobility, and reduces heat stress.

ii. Gusseted Sewing

Upper torso moving flexibility is very important for firefighters during operations. When moving arms forwards, upwards, backwards, etc., obvious sleeve withdraw and restrictions on upper area of arms were observed. These movements would easily cause protection gap between sleeve ends and gloves, and limited full reach of arm to different directions while moving arms. "Underarm gusseted sewing" was an innovative ergonomic design by using extra underarm insert or by extending the pieces of fabrics used. Both options could achieve the same effect of allowing full upper arm movement and less stressful resistance to motion, less coat rise, less sleeve restriction and greater reach.

iii. Pre-formed Padding/Articulated Knee

Climbing ladders, crawling on knees, etc. are routine activities of firefighters on the fireground. The "Pre-formed Padding & Articulated Knee" design applies a contoured pattern at the knee area to form a 3D configuration. This grants additional allowance for the bending of knee joints, reducing knee restriction experienced by wearers.

c. Materials & Weight

Careful selection of materials and appropriate design can facilitate heat and mass transfer from the body. The type of fibers in various layers, the weight and thickness of fabrics and the final design of the FFPS are the crucial factors determining performance and comfort.

d. Colour

For the past two decades, the SCDF FFPS has always been in a dark navy colour. Colour is important, not only making it easy to see if it is contaminated but also contributing to thermal heat protection by radiating heat away from the suit. Thus the SCDF Next Generation FFPS has adopted a new light gold colour.

MOVING FORWARD

There is always a demand for FFPS with improved safety and comfort. The nature and type of fires is changing especially in structural firefighting due to the use of new materials, paints and interior designs. Hence, the FFPS used by firefighters needs to be modified for adequate protection from new threats. Multifunctional and multi-hazard clothing can be developed to provide additional functions. The advancement of technology and creation of new designs can help to meet these requirements.

CONCLUSION

The SCDF FFPS is designed to protect our firefighters from all possible hazards during work and should provide thermo-physiological comfort. These two requirements are often contradictory. The FFPS is usually heavy, thick with multiple layers, which reduces water vapour permeability and heat exchange across layers from body to the environment. This results in our firefighters facing heat stress caused by the highly physical activity and excessive exposure to heat, which overloads the metabolic system. The SCDF Next Generation FFPS resolves these issues and strikes a balance between protection and comfort.

STAYING AHEAD OF THE RESCUE CURVE: MOBILE APP TRIAL FOR DETECTING MOTION OF BUILDINGS

LTC Lok Wee Keong
DART Commander
Operations Department

Dr Terence Tan
Deputy Director (Q1)
Principal Member of Technical Staff (Intel & Cyber Analytics)
Q Team Centre of Expertise, Capability Development
Home Team Science & Technology Agency

CPT Sia Peir Hong
DART Rota Commander
Operations Department

EDITORIAL PREVIEW

Wonder how a ubiquitous device like a smartphone with a camera can save lives by detecting the subtle movements of a partially collapsed building?

During Humanitarian Assistance and Disaster Relief (HADR) missions, especially in the context of an aftermath of an earthquake, SCDF rescuers are subjected to the risks of aftershocks and secondary collapse while carrying out Urban Search and Rescue (USAR) operations in collapsed rubbles. Currently, the SCDF Operation Lionheart contingent uses motion detection equipment (similar to those used in the building industry) and vibration detectors to monitor the movement of a collapsed building for possible tilt or shift, and to act as a safety aid to alert the rescuers operating in the rubbles. The motion detection equipment needs constant monitoring by rescue engineers and while newer technology allows auto-monitoring and alert functions to be incorporated, the equipment is costly and will need to be calibrated routinely to maintain its operational effectiveness.

SCDF collaborated with Home Team Science and Technology Agency (HTX), Q Team, to develop an Android application prototype, named TILDE (acronym for TILT DETECT). Using the image-capturing function of a smartphone to measure and monitor the movement of damaged buildings, TILDE can detect subtle building movement and alert rescuers to the imminent dangers.

This article elaborates on the development of an ingenious phone application TILDE by HTX, Q Team, to alert rescuers to any building movement when conducting search and rescue operations in a damaged structure.

INTRODUCTION

SCDF is the first organisation in the Asia-Pacific region to be classified as a Heavy Urban Search and Rescue (USAR) team by the International Search and Rescue Advisory Group (INSARAG) in 2008.[1] At the point of writing, SCDF has been deployed for 19 overseas missions. Of the 19 missions, 13 involved earthquakes, 3 involved bush fires, and 3 involved flood responses.

In a disaster-stricken area, there might be survivors trapped within partially collapsed buildings. USAR operations, which involve deploying rescuers to partially collapsed buildings for breaking, cutting or drilling, will be conducted to rescue the survivors.

Due to unendurable working conditions and fatigue experienced during the operations, rescuers might miss telltale signs of further collapse. As such, early detection devices that can monitor the movement of structures are important and are placed at strategic locations to monitor and alert the rescuers to looming dangers before the commencement of any USAR operations.

MONITORING DEVICES USED BY SCDF

SCDF deploys several types of monitoring devices when conducting USAR operations, including a vibration detector that automatically alerts users if it detects vibrations and total station, an optical device that can be used to track if the damaged building has shifted.

Both the vibration detector and total station are useful tools for detecting movements, but each has its limitations. On one hand, the vibration detector has a limited detection range, being only able to detect vibrations that are in direct contact with it. The vibration detector is also susceptible to false positives. Drilling and breaking are common during USAR operations. Occasionally such actions have to be performed near the vibration detector and would trigger the alarm, resulting in a false positive. It is possible to decrease the vibration detector's sensitivity; however, this might result in false negatives, where the system is unable to detect tremors.

On the other hand, the setup of the total station is complicated and might not be intuitive for users. The total station requires users to constantly monitor the building, which can be taxing on the user, and fatigue might result in human errors. Lastly, these devices are limited in number as they are costly and require maintenance to ensure their operability. With these limitations as the problem statement, SCDF turned to HTX for solutions.

Figure 1: Image of a vibration detector. The detector's alarm would be triggered if the concrete slab moves.

Figure 2: Image of a total station. Users view an object from a distance through the lens of the total station. With the marking on the lens, the user can determine if the object has shifted.

[1] INSARAG methodology is a set of USAR practices recommended by INSARAG. It aims to establish a common understanding amongst USAR teams from various countries and to improve coordination between the different teams. A team certified as heavy would be able to conduct USAR operations at two different worksites concurrently.

PROPOSED SOLUTION

Instead of dwelling on the physics of the total station, HTX, Q Team, took a step back and wondered if machine learning in Computer Vision (CV) could work. CV has been used to track the movement of vehicles, persons, and even small objects such as eye movement. As such, it should be able to track movements in buildings as well. Q team proceeded to test if CV can be used to detect buildings, particularly the edges of a building. The image below shows existing work in edge detection, which increased the team's confidence in the feasibility of the idea.

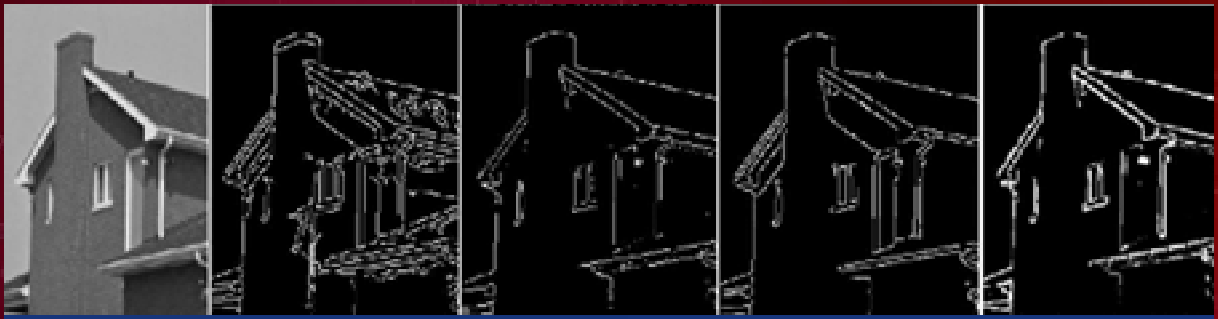


Figure 3: An existing work in edge detection.

OBJECTIVE AND METHODOLOGY

Preparation

The magic behind building movement tracking is the optical flow computed between two consecutive frames of images in a video. Optical flow is the pattern of apparent motion of image objects between the frames caused by the movement of an object or camera. The movement of points from the first frame to the second can be illustrated in figure 4: an image of a ball moving across five frames.

Optical flow assumes that the pixel intensities of an object do not change between consecutive frames and neighbouring pixels have similar motions. This means that users must ensure the video-capturing device is stable and secured before commencing with the tracking. The optical flow equation used is the Lucas-Kanade method,[2] which tracks a few points around the area of interest to improve trackability.

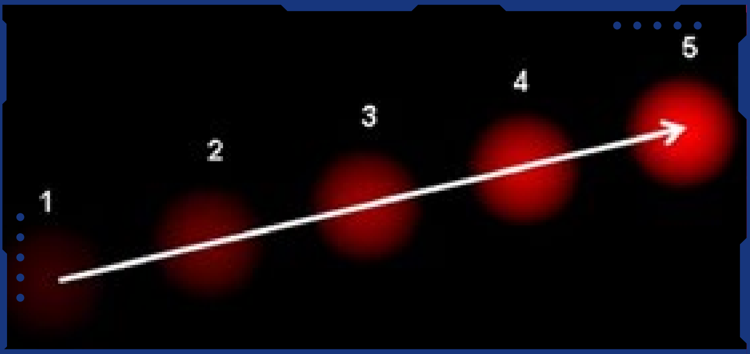


Figure 4: Optical flow of a moving ball (Image courtesy: Wikipedia article on Optical Flow).

[2] The Lucas-Kanade method (developed by Bruce D. Lucas and Takeo Kanade) is used to estimate optical flow. Source: B. D. Lucas and T. Kanade (1981), "An iterative image registration technique with an application to stereo vision".

Method / Findings

When developing the monitoring tool, the project team listed the following: the tool should be value for money, have an intuitive user interface, and be upgradable should the requirements change.

With those considerations in mind, Q team explored the possibility of developing an Android application using a Python library, namely OpenCV (Open-Source Computer Vision Library).[3] The library is free for use under the open-source Apache 2 License.

Q team managed to develop an Android application that uses the phone's camera function to detect the edges of a building, together with an intuitive touchscreen user interface. In addition, the application can be easily downloaded and installed on Android phones.

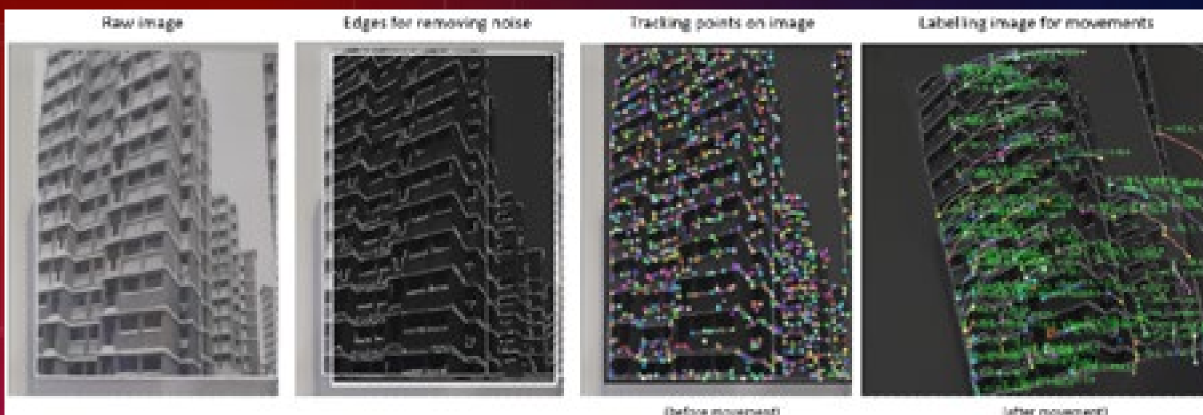


Figure 5: The first image from the left shows a photograph of a HDB flat. The second image shows edges that are gathered to provide possible points to track, instead of tracking all pixels in the entire frame. The third image shows the ideals points being selected to improve tracking. The fourth image shows how tracking is done when the photo is tilted.

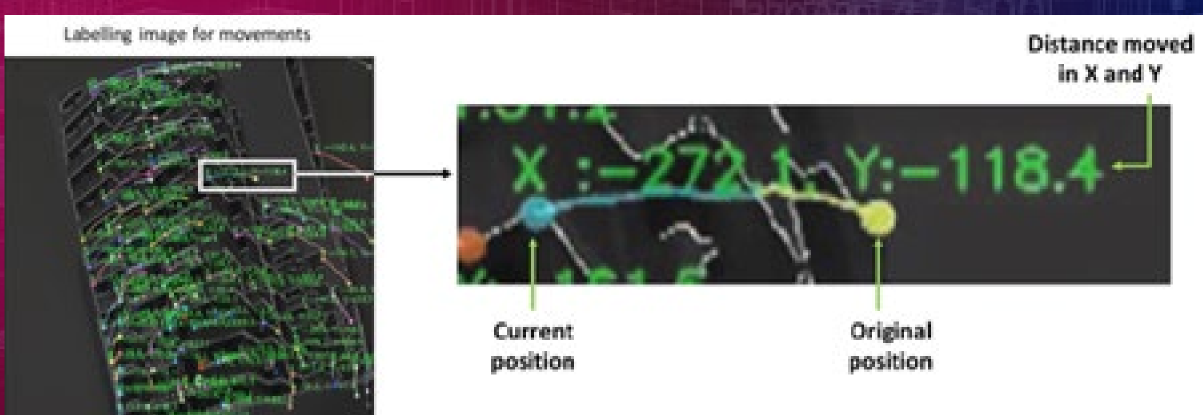


Figure 6: The left image shows the tracked points on the building while the right image is a zoomed-in image of the left to show the movement of the tracked points.

[3] A library of programming functions for real-time computer vision.

Objective

TILDE in theory is programmed to automatically capture edges of a building and compare the captured images frame by frame to determine if the edges have shifted.

Following the development of TILDE, the next step was for Q Team to design a series of tests to ascertain TILDE's real-world functionality. The overarching objectives were to determine if TILDE could detect subtle movements at a safe distance, in both day and limited lighting conditions, and determine the working limits of TILDE.

Tests and Results

Q team conducted the pilot test to determine if TILDE could detect edges automatically and if small movements could be captured and displayed on the user interface. As illustrated in the image below, points around the white label are automatically selected for tracking. Also, when the screen is tilted, white lines are shown on the user interface. These white lines traced the path travelled by the tracked points.

Figure 7: An image showing the user interface of TILDE. Observe how the points around the white label are selected for tracking. The white lines are the path travelled by the tracked points.

Riding on the success of the first test, Q team designed and conducted more deliberate tests. Q team programmed a robot to rotate at the speed of 1^{o}/sec, 1^{o}/min and 1^{o}/hour (1^{o} movement is the smallest movement option available, translating to about 3.5mm) with the camera placed 0.5m away. The aim of the test is to determine if TILDE could detect small and slow movements as sometimes damaged buildings or load-bearing structures might give way gradually and such gradual movements might not be detected by rescuers working in the area. Through the test, the team was able to ascertain that TILDE could detect movement at the three speeds.

Figure 8: Setup of the second experiment where the robot was programmed to move at different speeds: 1^{0}/sec, 1^{0}/min and 1^{0}/hour.

In the next test, Q team wanted to determine the working range of TILDE by waving a red cardboard in a HDB block at various distances from the camera. Q team determined that the farthest distance the TILDE could accurately detect small movement was at 50m.

Figure 9: HTX conducting a test to ascertain that TILDE could detect distant movements.

Confident that TILDE would work, Q team proceeded to conduct a proof of concept with SCDF at Kallang Fire Station using cardboard boxes and a trolley. The setup is shown in the image below.

Figure 10: TILDE was able to detect 1cm movement from 30m away, and 2cm movement from 50m away. The white dots indicate the corners that are detected by TILDE.

Q team and SCDF conducted several day and night trials. Q team used a trolley with cardboard boxes to simulate buildings. TILDE was installed on an SCDF-issued Samsung S21 phone with 10x zoom. The camera phone was placed 50m away from the cardboard boxes. When the go signal was given, Q team would move the trolley. The distance between the camera phone and the cardboard boxes varied between 30m and 50m. The distance moved by the trolley varied from 1cm to 5cm. The lighting level varied from 50lux to 200lux.

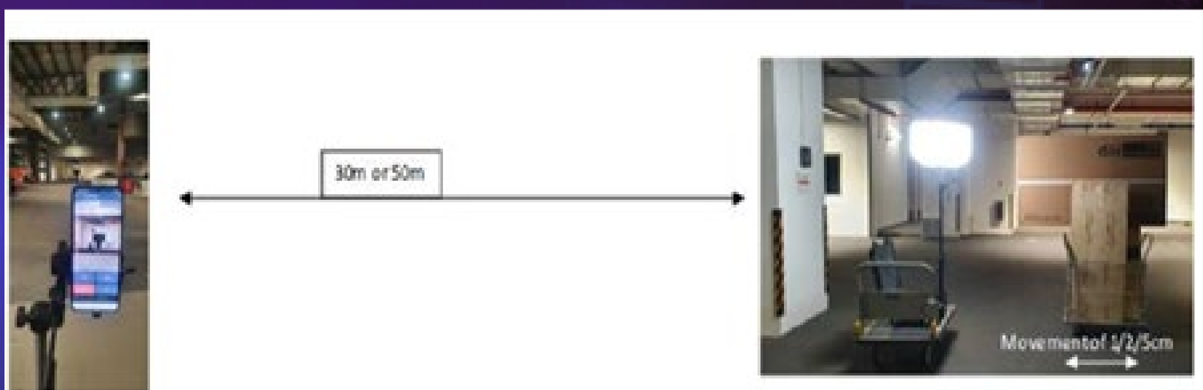


Figure 11: The setup of a night trial to simulate night operation conditions.

The observations are listed below:

- During the day trial, TILDE detected 1cm movement from 30m away, and 2cm movement from 50m away;
- During the night trial, TILDE needed 160lux of light to detect 2cm movement from 30m away. At 50m, TILDE is unstable and unable to consistently detect movements; and
- SCDF's lamp generated 10000lux but recorded 500lux on the boxes measured at close range, gradually reduced to 40lux from 50m away between the phone and boxes.

LIMITATIONS

As TILDE is based on the principle of CV, field conditions such as raindrops/fog could interfere with detection and TILDE is unable to work in the dark. Special effort is required to overcome them in operation. For example, a light source is needed to shine directly at the area of interest to allow TILDE to accurately capture any movement within the area of interest.

CONCLUSION AND FUTURE WORKS

Detecting building movement is an important safety measure in USAR operations. SCDF has traditionally relied on optical and vibration detectors, which introduced its own set of operational issues. HTX understood those challenges and was able to leverage CV methods to overcome the challenges faced.

Through the proof of concept, SCDF and Q team are convinced that TILDE would be able to detect subtle building movements and provide warning to rescuers working in disaster-stricken areas.

With the success of the trial, TILDE 2.0 is further refined for operational use. TILDE 2.0 would include new functions such as distance finder, lux intensity display, and displaying the angle of lean of damaged buildings. For future iterations of TILDE, the project team aims to make TILDE "smart" by enabling the analysis of data gathered and automatically alerting rescuers to imminent collapses, preventing the loss of lives.

TRANSFORMING SCDF'S OPERATIONS THROUGH A NATIONWIDE SENSOR GRID

LTC Zhou Yan Sheng
Senior Assistant Director (Plans & Policy)
HazMat Department

CPT Tyanne Choo Sha-Wei
SO HazMat Policy
HazMat Department

LTA Liew Shah Yu Grace
SO HazMat Development (Systems)
HazMat Department

EDITORIAL PREVIEW

To provide early warning of an imminent Hazardous Materials (HazMat) incident, which may arise from industrial accidents, terrorist attacks or wartime emergencies, SCDF is developing a real-time 24/7 nationwide sensor network to monitor and detect a range of HazMat. In developing the nationwide sensor grid, SCDF partnered the Home Team Science and Technology Agency (HTX), DSO National Laboratories (DSO) and Defence Science and Technology Agency (DSTA) on various technological fronts to develop sensors and supporting systems that are suitable for local context and environment.

In a HazMat incident, quick detection of the chemical and constant monitoring of the ambient hazard level are critical. This will enable SCDF to determine the areas affected by the chemical plume so that appropriate and timely public protective actions such as In-Place Protection (IPP) or evacuation can be implemented, and frontline resources can be deployed accordingly.

INTRODUCTION

HazMat incidents may involve chemical, biological, radiological or explosive agents capable of causing loss of life, injury to a person, or damage to a person's health or to the environment. HazMat may arise from industrial accidents, terrorist attacks or wartime emergencies. During a HazMat incident, emergency responders will go on-site to perform detection, identification, monitoring and mitigating tasks.

The monitoring task during a HazMat incident is challenging on various fronts. The dynamic nature of the chemical plume due to changing wind conditions means that responders often must play catch-up as the plume is likely to have dissipated or drifted before they arrive. The lack of an early warning system to alert and notify SCDF of a potential HazMat incident amplifies the response lag as responders attempt to verify the presence and movement of the plume. Further, in incidents where information on the source of release is unknown, SCDF would be unable to accurately predict the plume's trajectory – the lack of critical information required for timely implementation of the appropriate public protective actions would result in members of public being exposed to the chemical plume leading to an increased risk of health effects or even death.

The development of a nationwide sensor grid was initiated with the primary objective of providing early warning should a HazMat incident occur, as this would allow the necessary resources to be dispatched swiftly and decisively for follow-up mitigation. The nationwide sensor grid comprises multiple Whole of Government (WoG) fixed chemical, biological and radiological sensors placed across the country. With the real-time sensor network data available, integrating the sensor data with sense-making technology allows for the plume projection to be predicted more accurately. The HazMat Incident Management System (HIMS) 2 is a command and control system used to assess, monitor and manage HazMat incidents and is the centrepiece of the sensor grid to aggregate various sensor data into a common situational picture. HIMS 2 is also a decision support system that was conceived to enhance SCDF's capabilities and is able to gather, generate, and disseminate information critical to the HazMat incident rapidly, provide sophisticated and accurate hazard plume models relevant to Singapore's context and seamlessly integrate with other SCDF command and control networks and existing databases.

The growing availability of real-time data from the nationwide sensor grid allows SCDF to explore integrating the data with sense-making technology to enhance our predictive plume modelling capability. This will allow for a more accurate projection of the areas that would be affected by the toxic plume and enable timely public protection actions.

SCDF is currently working with the Home Team Science and Technology Agency (HTX), DSO National Laboratories (DSO) and Defence Science and Technology Agency (DSTA) on various technological fronts to develop sensors and supporting systems that are suitable for local context and environment.

SENSOR DEPLOYMENT

The development of a real-time 24/7 nationwide sensor network to detect anomalies in the atmosphere allows for early warning of a HazMat incident. Fixed chemical standoff and point-source sensors will be installed at various locations in Singapore as part of this sensor network. These sensors will alert SCDF at the earliest possible time. The early warning is critical to ensure SCDF can swiftly initiate public protective measures and deploy frontline resources accordingly. This includes island-wide 24/7 "sentinel" monitoring sensors to provide early warning and hazard mapping capabilities that take in WOG sensor data to establish a comprehensive picture of the chemical plume dispersion in an incident.

SCDF is also deploying an electronic nose (e-Nose) network, which comprises multiple chemical sensors. These sensors can detect chemical anomalies at very low concentrations present in the air and provide SCDF with yet another early warning capability. Deployed as a network, e-Noses can track the chemical's movement accurately, demarcate the hazard zones and pinpoint the source through triangulation. Each e-Nose consists of four metal oxide semiconductor sensors, which respond to gases present in the air through a reaction between the gas and the metal oxide surface. Upon detecting an anomaly in the air, the e-Nose will alert SCDF who would be able to check a web-based application which displays a map indicating which e-Nose triggered the alert.

It is envisaged that the deployment of fixed chemical sensors will be complemented by Unmanned Aerial Vehicles (UAVs) mounted with chemical detectors that can fly Beyond Visual Line of Sight (BVLOS) for targeted monitoring in areas not covered by the sensor network. With large area monitoring covered by the network of fixed sensors and the BVLOS UAVs, on-site monitoring at the immediate source of release will be undertaken by the HazMat Control Vehicles (HCVs), which are equipped with advanced HazMat detection and identification systems such as Gas Chromatography Mass Spectrometer (GCMS) and complemented by Unmanned Ground Vehicles (UGVs) such as Rover X and the Autonomous Casualty Transporter (ACT) 2.0. In addition to UGVs, Line of Sight (LOA) UAVs attached with surveillance cameras and detectors will also be used to survey hard-to-access places.

PREDICTIVE PLUME MODELLING

Despite ongoing efforts to provide early warning and situational awareness in a HazMat incident, the ability to accurately predict the plume development in an incident through hazard prediction modelling, particularly at the early stages of an operation, remains a challenge for SCDF. SCDF currently utilises dispersion modelling software to analyse plume propagation and determine the worst-case scenario for planning purposes.

During an incident, such models are critical to predict the affected areas and determine the lead time to implement public protective actions. To accurately predict the plume's trajectory, data for the modelling software must be precise. This includes information on geographical conditions, chemical storage conditions and the extent of the release. In most situations, such information is unavailable at the onset of the incident and relying on estimation affects the model's accuracy.

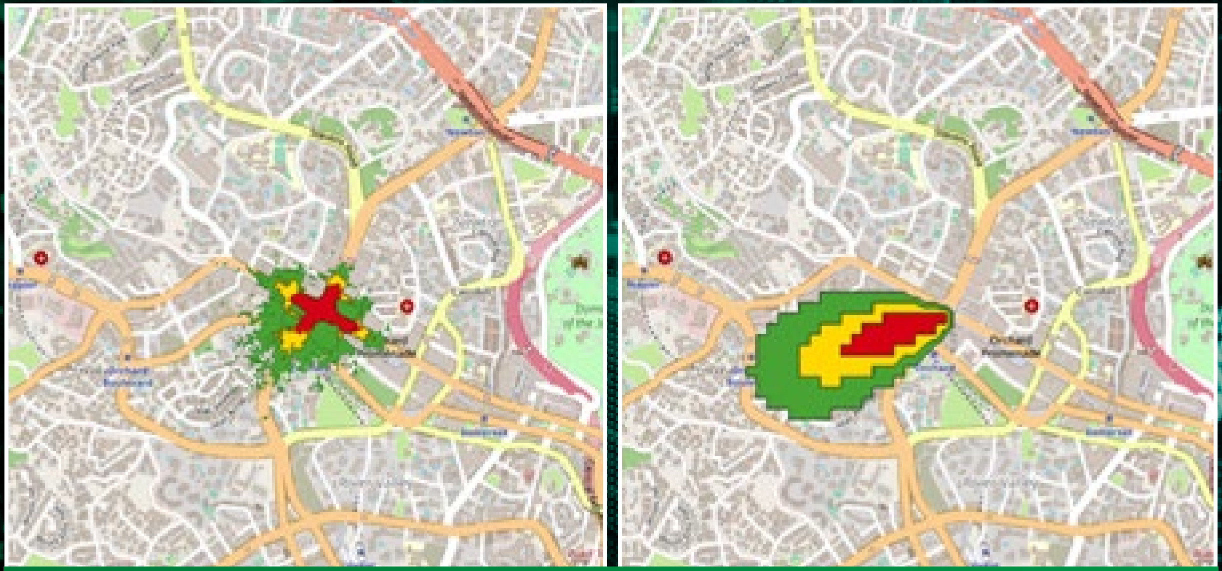


Figure 1: Plume Modelling With vs Without Buildings

With advancements in technology and availability of the real-time sensor network data, SCDF can enhance its predictive plume modelling capability by incorporating the data with sense-making technology. Enhancing the predictive plume modelling capability allows for a more accurate projection of the areas that would be affected by the chemical plume and enables SCDF to operate with greater effectiveness and initiate timely public protective actions. In addition to reducing the exposure and risk of health effects to members of the public, there would also be reduced economic losses and disruption to daily life.

Existing dispersion software generates static plume models using information relating to the source of release and weather conditions. In most incidents, this information may not be available or updated and when the information becomes available, the resultant model is likely to be inaccurate. Dynamic plume modelling tools, however, reduce the need for precise information on the source by ingesting real-time sensor data into advanced algorithms to make accurate and timely alterations to the plume prediction.

Figure 2: Modelling Output with Live Wind Measurements

With real-time data from the nationwide sensor grid, SCDF is working with DSO and HTX to develop a first-of-its-kind set of dynamic plume modelling tools. When a HazMat leak occurs, these modelling tools will automatically process real-time data from the sensor network to forecast the trajectory and extent of a plume over a stipulated period. Areas potentially affected by the plume will be identified for immediate implementation of public protective actions.

CONCLUSION

To enable key decisions and critical actions in a HazMat incident, continuous HazMat monitoring must be conducted throughout the operation. The magnitude and scale of a HazMat incident will be alleviated with early warning systems in place to initiate prompt response actions. By harnessing new technology to enhance our monitoring and predictive plume modelling capabilities, SCDF will be able to manage HazMat incidents more effectively in Singapore.

OPERATIONAL CONCERNS INVOLVING ELECTRIC AND HYBRID VEHICLES AT VEHICLE-RELATED INCIDENTS — PART 1

David Dalrymple
Volunteer FF/EMT/Rescue Technician
Clinton EMS/Rescue

One of the largest concerns today dealing with vehicle-related incidents is the electrification of vehicles. We deal with technology concerns in every single vehicle that we encounter, whether passenger or commercial. SRS safety systems are more and more comprehensive, but materials and vehicle construction techniques coupled with this issue is what is injuring the vehicle's occupants. So, take those and add them to the additional issues of alternative fuelled vehicles. Take a seat, sit back, and lend me your ear!

For the most part electric vehicles (EV) and hybrid electric vehicles are not hugely different from conventional-drivetrain vehicles to manage and mitigate in terms of extrication, so long as you can remember simple common-sense guidelines. Power isolation is critical and that applies across the board today. Chock the vehicle so it cannot move, then make sure to shut off and remove the vehicle key from the vehicle and place it in your apparatus.

Why? We cannot rely upon our hearing to ensure that the vehicle is turned off due to stop/start and EV/hybrid technology. We need to physically shut the vehicle off. The key removal is like a lock-out tag out in confined space. Most ignition keys today are wireless, so they need to be out of the range of the vehicle, and at least 15ft is a good rule of thumb. Now here is a tip: if there is a family in the vehicle, check to ensure that you have all the vehicle keys.

Remember, just because you took the driver's key does not mean there is not another key present, which the car may switch to. This action does two especially important things: first, it depowers all the vehicle SRS safety systems so that they are electronically dead; second, if the vehicle is an EV or hybrid, it starts the depower of the high-voltage circuit. There is a drain time associated with this, depending upon the vehicle, which is no more than a few minutes. That is half of power isolation.

The second half is to take the 12V battery out of the loop. Today's best practice is to double cut both battery cables. Now with today's vehicles we need to identify interior items that are powered that might need to be operated before 12V battery power is removed.

The other issue is finding the 12V battery following crash damage and the simple fact that in over 50% of vehicles the battery is no longer in the front in the engine bay. If not, then more than likely it will be in the rear of the vehicle. High-end vehicles can have multiple batteries as well. So that is power isolation, and you should be doing this on every injury-producing MVC.

The other common-sense guideline is remembering that orange-cable device connections are industry standard for high-voltage power (40V or more) so do not cut them or mess with them in any way! There really is no reason to do so and after 20 years of hybrids being on the streets, now EVs have all the high-voltage cabling away from where tool evolutions would normally be done. However, there are a handful of exceptions for extrication dealing with EVs and hybrids but more on those later.

One of the best ways to assist yourself at a vehicle-related incident is to have your smartphone and/or tablet equipped with the right apps to give you data on scene. We are all professionals and we all want to strive for a better outcome for every patient we encounter. This sort of information is now a critical on-scene tool to help in making mitigation and management choices. Where is the 12V battery and is there more than one? Can my power hydraulic rescue tools cut, push, sever vehicle components? Is this vehicle an EV or a hybrid or a conventional? All these types of questions and more involve time, effort and energy. And remember trauma is the disease of time! All these questions gobble up precious time and we need to put time back onto our side.

2020 Model Chevrolet Bolt engine bay

Examples of on-scene electronic apps to assist responders at a motor vehicle collision.

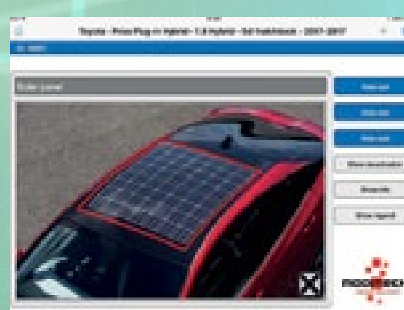
So, let us talk about these apps. This whole field has rapidly expanded in the past ten years. The longest one around and the gold standard for many to hold to is Moditech CRS (Crash Recovery Software). This started out as software on a laptop based in 2004 but today is a smartphone and tablet-based app. The correct vehicle can be found by its number/licence plate, VIN number, scanned QR code and manual search. The app then shows a glass cutaway of the vehicle with colour-coded hazards. If the vehicle is an alternative-fuel vehicle, a splash screen alert advises you that the vehicle is such and needs to be depowered. The app then walks you through the primary, secondary and tertiary methods of shutting down the vehicle. The app advises on any high-strength reinforcements and what force is needed to sever them. Vehicle fire tactics are given as well. The app has a database available for all regions of the world. This app is not free but does not cost a lot either.

Rescue Code is a similar app with glass cutaway vehicles and colour-coded hazards much like Moditech but simpler and with no in-depth background information like Moditech. North American vehicles are not featured on this app but can be figured out by comparison. This app is manual search only. Along with Rescue Code, Rescue Sheets is also based along the same lines. Rescue Sheets is paired off the ISO refs for alternative-fuelled labelling and has more information than Rescue Code. Both Rescue Code and Rescue Sheets are free. However, Rescue Sheets does not currently work in North America and it is unknown when or if it will be.

NFPA makes an app that is just for EV and hybrid vehicles, which uses Moditech CRS screen shots and has good background information. The NFPA app is focused on North American vehicles, but it is free. Lastly there are two vehicle manufacturers who place vehicle Rescue Sheet information right onto the vehicle and it is available all the time. The first is Mercedes Benz who from November 2013 have fitted a QR code sticker on the inside of the fuel filler door and another on the inside of the driver door opening on the B post. You scan them with your phone or tablet and then that vehicle's Rescue Sheet is displayed. What about prior to that date? As older vehicles come into the dealer for service, the dealer retrofits them with the correct QR sticker. Someone looks out for us; they just need to tell more of us.

The second manufacturer is GM and they only do this on their EV and hybrid vehicles. Same location and device as Mercedes Benz. So rescuers check these apps out, load them up on your device, or a device to be used on scene, and you will be surprised how much they empower you and put you at ease. Another thing to remember is that these apps can be a great learning tool for training as well. The best thing about all these apps is they are available on all platforms – iOS, Android, Windows.

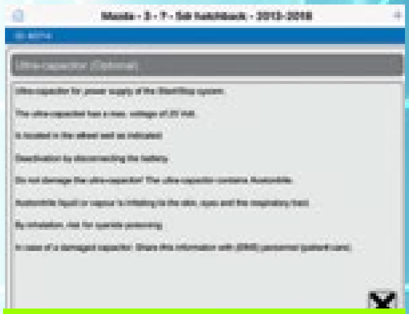
2017 Chevrolet Volt 12V battery emergency responder disconnect area.



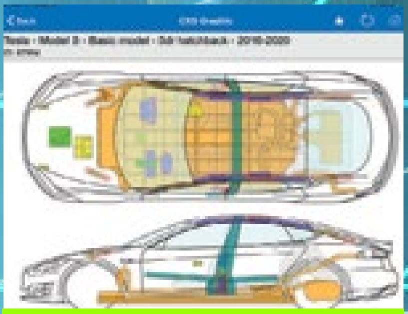
Current generation Prius glass roof extrication hazard (Moditech screen shot).

Current generation Prius glass roof extrication hazard (Moditech screen shot).

Centre dash ram push evolution on a Ford F-350 Super Duty crew cab pickup truck.



Stop/start ultra-capacitor hazards (Moditech screen shot).



Tesla Model S vehicle floor/battery pack lifting/dash displacement hazard (Moditech screen shot).

Back to our physical operations. Extrication-wise EVs and hybrids have but a few differences to conventional-drivetrain vehicles. Most of our tool evolutions performed on the vehicle structure are away from the high-voltage battery, cables and electric motors. Therefore, I feel that these vehicles, if you perform power isolation, are the same hazard level as a conventional-drivetrain vehicle. This is especially important. So, all the best practices that you use for technology concerns in conventional-drivetrain vehicles need to be done here as well. But there are some considerations to be aware of. Watch for oddly weighted vehicles in precarious placements for stabilizing due to the placement of the high-voltage battery. Watch when lifting the bottom of the vehicle due to the HV cables and/or floor being the HV battery, trunk tunnelling could be impossible due to HV battery placement (the same goes for the floor) and always remember to pull interior trim to check for SRS cylinders. And remember, even with power isolation, if you cut through an uninflated SRS curtain cylinder, it will go off. Also do not forget, SRS side-curtain cylinders can be found on either end of the curtain bag, in the middle above the B post and even inside the curtain bag itself around the B post area.

Here are three specific technology concerns for extrication that are directly related to an EV or hybrid vehicle. The latest version of the Toyota Prius Solar Roof needs to be covered with a heavy-duty tarp that is lightproof to halt its ability to generate 60V power to the HV battery. Also, the actual cable from the solar roof to the HV battery is in the driver-side C post and this should not be cut through while energized. Fire concerns are the same as any alternative-fuel vehicle, but the solar roof does add additional concerns. Europe and the Far East will see these latest versions, but North America does not as the glass roof will break upon roll over.

Next is the concern of the ultra/super capacitors in stop/start systems. I believe the concerns with these were drain time and what action was the tipping point of that drain time start. Another concern was the location. Certain rescue-tool operations might damage the unit and it is a significant respiratory concern for patients and rescuers. Currently only Mazda fields vehicles with these devices in North America, but in Europe and the Far East many other manufacturers do.

The last vehicles to mention specifically are Tesla models. All their vehicles use a floor-mounted HV battery pack. You need to use caution when lifting the vehicle with any tool, but be sure to crib as you go. The biggest concern is dash displacement. This is a vehicle where a conventional dash roll will not work well without a crumple zone relief cut. But a dash lift really needs to be used with due caution. You do not want to crush the floor and in doing so crush power cells in the HV battery. Doing that would start a thermal runaway in the HV battery, i.e. FIRE!

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AI AND THE CLOUD: DIGITAL TRANSFORMATION IN PUBLIC SAFETY

Nick Chorley
Director, EMEA Public Safety & Security
Hexagon's Safety, Infrastructure and Geospatial Division

Public safety is a high-pressure sector, and digital transformation can yield the dynamism needed to tackle the scale, complexity and unpredictability of fluid, multi-dimensional incidents, as well as complex legislative demands.

Collaboration between public-safety agencies is vital to keeping the people of any region safe and improving their quality of life. The key to effective collaboration is a technology foundation that ensures all relevant emergency services are connected and receive the necessary information as quickly as possible for effective mobilisation and decision-making. Increasingly that foundation is built on the cloud and features advanced capabilities such as real-time artificial intelligence.

Cloud-based systems can help emergency response agencies fulfil the vital criteria of easier integration between all the systems they depend on and scalability during larger incidents when more resources are required. Additionally, embracing emerging assistive artificial intelligence (AI) strategies will help improve decision-making further for a more effective response.

MULTIPLE LAYERS OF EMERGENCY SERVICE STRUCTURE

In the UK, the government is looking to streamline emergency service integration and collaboration. However, it is complicated because there is such a variety of different authorities responsible for setting policy and overseeing service delivery amongst the emergency services. These commissioning authorities differ between the three services in their geographical scale and their local political accountability and often have boundaries that are not coterminous. Further, the commissioning authorities can even differ by location and the scope of their authority leading to different priorities and local agendas.

First responders must react to fast-moving events on the ground.

For example, in most areas fire and rescue services fall under the control of fire authorities, which are typically county based. But in some counties, these have been replaced by locally elected Police, Fire & Crime commissioners that combine this function with the governance of the local county police force; and in metropolitan areas where there is an elected mayor their office sometimes performs this function. The Police service and its elected commissioners are also generally county based but there are a number of mergers and in these cases there can be several county fire services for one police.

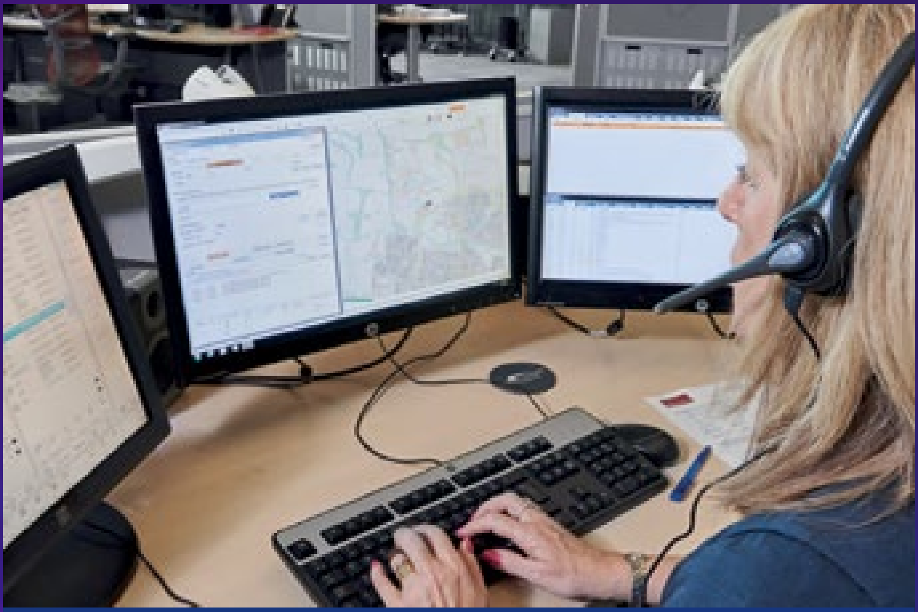
Moreover, since 2008 ambulance services have been managed regionally and commissioned within the National Health Service, covering much larger areas, to a national agenda and typically working alongside four or five different fire and police agencies working to more local priorities. This complexity introduces barriers to information flow that, in the interests of public safety, must be overcome. Cloud-based systems can act as a bridge between the different public safety authorities in each locality.

Another significant issue is that different organisations may have competing political priorities, as well as their own legacy IT systems, which act as barriers to comprehensive integration. This is another obstacle cloud can help overcome.

THE ADVANTAGES OF CLOUD-BASED SYSTEMS

There are many benefits to moving public safety systems, such as computer aided dispatch, into cloud-based architectures. For example, they offer greater access, flexible connectivity and communication through a government-accredited, secure platform between all organisations. A shift to the cloud facilitates better informed and more prompt decision-making by public-safety agencies. This optimises the use of resources, as the right personnel are appropriately directed when responding to an incident, which, in turn, boosts public trust in emergency response.

Cloud-based platforms create a shared point of access to data that cuts across regional and political boundaries. All emergency service organisations can access the same, security approved, information in real-time, improving coordination in a crisis event. This better protects both the lives of the public and first responders, as more efficient communication allows authorities to handle incidents quickly and effectively in coordination.



North West Fire Control UK.

THE ROLE OF AI

AI also has a key role to play in the digital transformation of emergency response. In a control room, AI can act as a second set of eyes, helping personnel make more informed decisions from large amounts of information and covering 'blind spots' that they might otherwise miss. While hundreds or thousands of calls for service may come into a control room each day, the ability to analyse data immediately to inform decisions is limited. Staff do the best they can to capture, process and convey information under pressure, but deeper analysis tends to happen after the fact, to inform and improve future performance.

Here, AI can play a positive role. For example, call takers and dispatchers dealing with dozens of calls during a major traffic accident might miss that a lorry involved in a crash was described by one witness as a 'tanker', which could indicate the presence of potentially hazardous materials. Having such information may be crucial to police, fire and ambulance crews dispatched to the scene. An AI component reviewing incoming data could flag that detail and alert all dispatchers, who could then assess the situation and inform first responders, so they could take necessary precautions.

However, AI alone has its limits. In incident response, AI must never be the sole decision-maker. Instead, there must always be a human involved in all decisionmaking. 'Assistive AI' is the answer. This is a framework through which AI augments, and acts as a force multiplier, but never replaces human judgement and intuition when swift decisions are required.

WIELDING TECHNOLOGICAL ADVANCES

When it comes to digital transformation in emergency response, there are clear next steps that must be taken for public-safety agencies. First, the use of the cloud should become more ubiquitous allowing for the sharing of information between agencies as they react to incidents on the ground. Then, the use of emergent AI technology can better inform agencies as they meet crisis events, with all information shared to the cloud. The spread of these technologies will yield multiple benefits to the public and first responders, as smarter, more responsive services lead to the saving of lives.

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3D TECHNOLOGY AND FIREFIGHTER TRAINING

Miguel A. Hernández Alfocea
Trainer in Rescue in Traffic Accidents,
Heavy Rescue and Air Rescue

The global pandemic is generating changes to our daily lives that no one imagined could happen. One of the consequences of Covid-19 is the need to establish security measures to protect us from infection. Measures such as social distancing and the use of masks have been established for an unlimited time since we do not know when we will be able to return to 'normal'.

It is these restrictive conditions that have led many to new forms of teaching, such as distance learning, or enhanced those that already existed, such as online training platforms.

One of the tools that can be of great help for this type of training is the 3D infographic that, together with its younger siblings virtual reality, mixed reality and augmented reality, is already being used widely in fields as diverse as gaming, medicine, engineering, aeronautics, judicial research, etc.

These four forms of computer modelling and sampling are very powerful because of their large graphical capacity and because they offer many possibilities to transmit information to the brain. If they are used responsibly, and integrated into the training process, they greatly improve the quality of teaching, increasing the ease of understanding and learning by students.

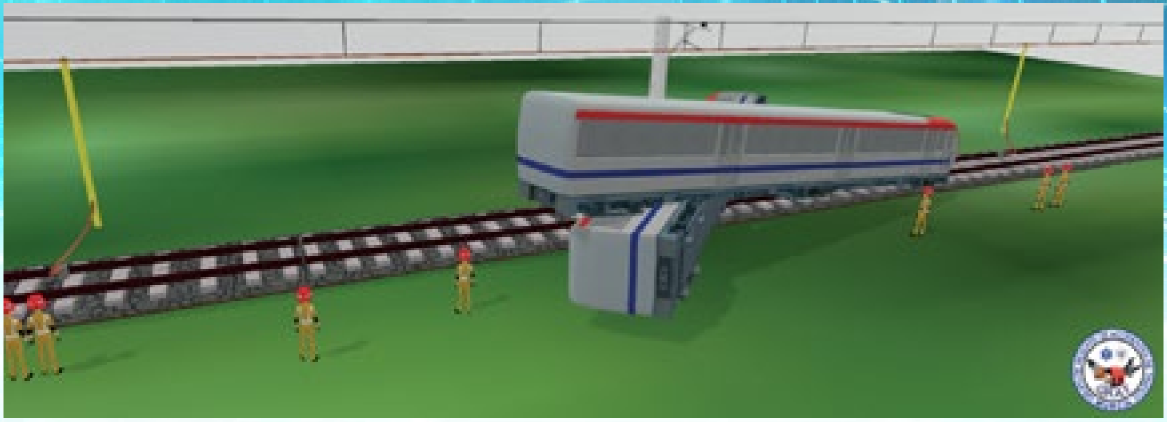
The constant advances in these technologies make them very versatile for training programmes, increasing their scope and allowing us to offer global views of scenes or incidents that otherwise our brain would not have the ability to process.

To us firefighters, these technologies can help us in training students by opening two lines of work that can be compatible with each other or independent, as we choose. On the one hand, they offer us the option to work online or remotely, since we can develop classes during periods of Covid restriction, creating classrooms over the Internet. And, on the other hand, if the training is face-to-face, with the use of sampling offered by these technologies we can reduce training hours in the classroom as well as in the field of manoeuvring, which results in a reduction in the economic costs of the courses.

I will try to show some examples based on traffic accidents. All the photographs I share in this article are taken in a 3D format and allow us to see them in three dimensions and in 360°. Examples of what 3D technology can bring to rescuers in training processes, both online and face-to-face, are:

- This technology can be found on the market in two formats. First, in the form of previously designed software where we can work through the different possibilities offered. They use high-resolution graphics that are very useful for use in training. Second, is the use of 3D programs to create different scenarios, manoeuvres, distribution of rescue personnel, etc. This option is not subject to limitations and everything depends on the imagination and creativity of the trainer, and also offers high-resolution graphics and great manoeuvrability. It is more economical but requires skill in software management and the dedication of more time to creating scenarios.

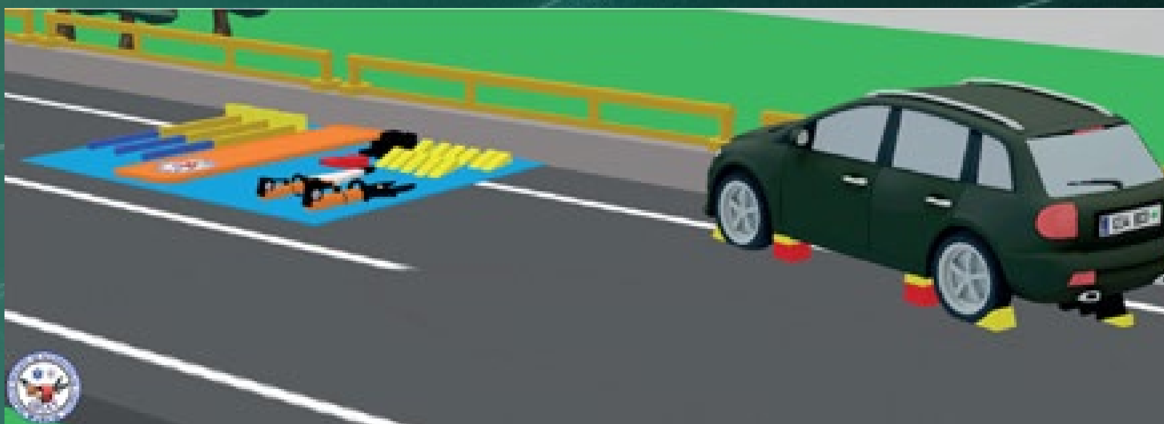
- The 3D infographic allows you to generate multiple scenarios of traffic accidents, railways and aeronautics. This allows us to show, to all students together, the details of the scenarios by increasing performance in the classroom and reducing the time in the field of manoeuvres.

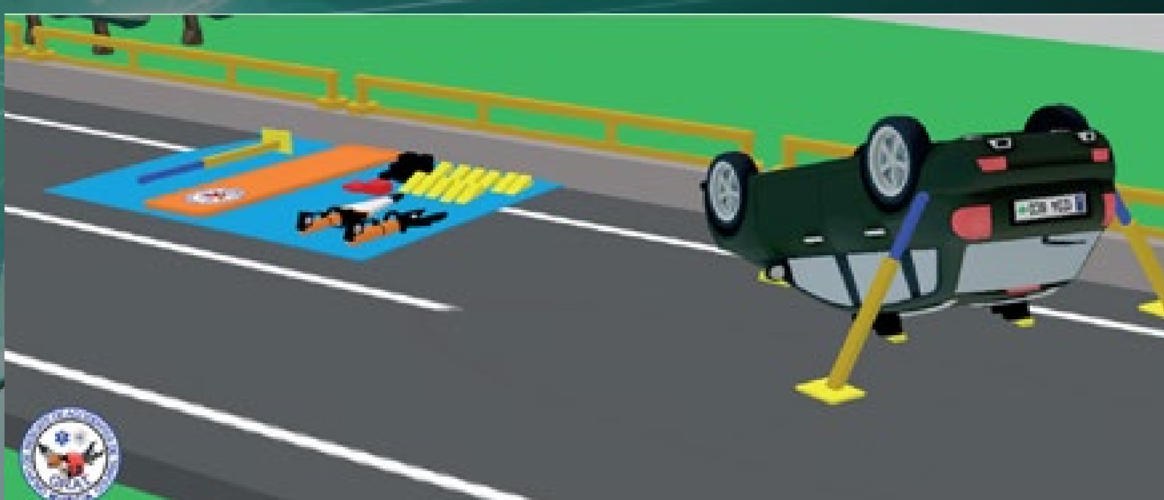


- We can show the position of the different emergency vehicles called to intervene. Looking at the photograph we can see how the organization of the emergency area must be established according to the degree of danger that exists. Zones red, yellow and blue are the spaces that have to be generated to ensure the safety of firefighters, paramedics and police, since electrical hazards, gas leakage, explosions, spills and other hazards can be found inside or around a crashed car.

- The 3D format allows us to visualize the different elements and their location within the vehicles, since it allows us the option to separate these elements and differentiate them from the general structure. For example, we can show the different powertrains that a vehicle can have as we see in the photo. This makes it easier for students to understand the spatial situation they occupy and where different fuel or/and electricity conductors may go.

- This technology allows us to perform and show different stabilization manoeuvres in any position that we put the vehicle, either on its wheels, in lateral rollover or total rollover, as well as performing vehicle stabilization simulations in any scenario we have previously developed. We are also able to display the area in 360° to see in detail the possible conditions under which the stabilizing elements can be placed.





- We can show where different cuts or/and material separations can be made to release injured occupants. This makes it possible to understand the various manoeuvres that can be performed for the release of people trapped in vehicles.

- Due to the possibilities offered by 3D technology, with a high degree of realism and the ability to show spaces, gaps and measures, we can contemplate the different possibilities and manoeuvres that we can perform for the extrication of injured people. This makes it easier for firefighters to make decisions when we have to execute an extrication manoeuvre in an emergency.

This 3D technology is a powerful tool for training firefighters and other rescue groups. It allows students to understand more easily and quickly the concepts covered by teaching with high-resolution graphics showing scenarios and possible manoeuvres to be performed in each situation. The different accidents designed can be viewed in three dimensions, with the ability to vary fields of view in 360°.

As we have seen in these examples, the use of these technologies in the rescue of injured people allows us to design, display, observe, clarify and/or discuss specific scenarios. This makes it easier to make decisions about the different ways to proceed with the rescue of people. All this can be done in the online or face-to-face classroom, depending on the training process due to the conditions that exist at that time due to the pandemic.

We need to keep in mind that while 3D technology offers many possibilities, it can't ultimately provide a real manoeuvre. Those of us who have some experience in rescuing people in accidents know that every situation is different. This makes the forces and stresses that are generated unique and specific to each accident and therefore the movement and behaviour of materials when cut, separated and/or eliminated, unique and characteristic of that accident.

These are the reasons why I think manoeuvres should always be practised in as real scenarios as possible. And if we have vehicles previously deformed by impacts, better for the development of the practice.

The optimal thing is to take the best of both forms. That is, if we can show a scenario with 3D technology and then go to the field for real manoeuvres at the same scenario, the quality of the training would increase greatly.

We also need to add the economic aspect. As 3D increases students' speed of understanding, it reduces training schedules. It causes a reduction in teaching hours, both in the classroom and in the field of manoeuvres, with the consequence of reducing the total economic budget of the course.

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IMMERSIVE LEARNING FOR THE FIRE SERVICE

Dr. Jeff Godfredson AFSM
Chief Fire Officer (Ret)
Metropolitan Fire Brigade, Melbourne, Australia
Past Director NFPA, Asia Pacific and Middle East
(Now Director International Relations FLAIM Systems)

Associate Professor James Mullins
Chief Technical Officer
FLAIM SYSTEMS

In May 2015 the National Fire Protection Association (NFPA) and National Institute of Standards and Technology (NIST) published an extensive report entitled 'Research Roadmap for Smart Firefighting'. The report spoke of the need for the fire service to take advantage of new and evolving technologies for realistic training including immersive reality, augmented reality and haptics. The new methods of training are now available for the fire service.

Simulation training is not new. We have all flown in planes where the pilot learnt and maintained their skills in simulators. The military has been using a wide range of simulators for skills and battle training. The police have been using shoot/no shoot simulators for decades. The quality of these simulators has improved over time and the current systems provide a very realistic experience.

There are many other industries now using Virtual Reality (VR) training, and these include medicine, business, education and space exploration to name a few.

WHAT IS THE DIFFERENCE BETWEEN VR AND IMMERSIVE REALITY?

Virtual Reality is a purely visual experience with content in the VR headset. Immersive Reality is much more. It is an experiential system made up of a combination of advanced learning theory, data science and advanced spatial design. It enables employees to train in a safe and engaging environment where the user also has a range of other sensory experiences. According to Edelman's Theory of Neuronal Group Selection (a theory about brain development), more elaborate brain connections form when multisensory learning occurs compared to single sensory learning.

Trainees experiencing flashover in Container Based Training (CBT) being exposed to the products of combustion.

The concept of learning by using multiple senses is supported by a large body of research. In a recent paper entitled 'Experiential Learning: An overview' Professor Joane Wright, Deputy Vice Chancellor, Queensland University built on Kolb's earlier work in this space. In essence experiential learning is a four-stage cycle. It begins with allowing participants to observe, review and reflect on their experience. They then need to reflect critically on the links between their experience and previous experiences or theory. Experiential learning is an ongoing process. The paper reinforces the current drivers of change and the need to address the required workforce skills for the future.

Another major issue for the fire service is to deal with the different generations within the workforce. They will learn and engage in different ways. The new technologies will assist in that process.

Current research shows retention rates of 75–90% for immersive learning compared to 20% for traditional audio visual/video training.

Immersive learning for the fire service has evolved into a multisensory learning experience. The latest technology now includes visuals of the fire, radiated heat levels proportional to the proximity of the fire, sounds from inside the building such as alarms, breaking glass and other background noise, and haptics in the form of jet reaction from the nozzle created by the force-feedback hose reel. The jet reaction is proportional to the pressure and volume of water being discharged. The sensory engagement enhances the learning experience and increases cognitive retention.

Photo of an immersive learning scenario involving three vehicles on the highway.

DOES IMMERSIVE LEARNING WORK?

Research undertaken by Stanford University and Technical University, Denmark showed that virtual learning produced significantly better results than conventional training. There was a 76% increase in learning effectiveness and retention rates improved by 75%. The School of Medicine, Atlanta found that VR-trained surgeons made 40% fewer mistakes than conventionally trained surgeons. Humans learn by ‘doing’ and we learn more from our failures than anything else.

In 2020 PWC published major research on three different learning methodologies: classroom, eLearning and v-learning (Immersive Learning). The study involved a large sample group spread over 12 different locations in the USA. The results for Immersive Learning were impressive.

- 275% more confident to act on what they learnt in training
- 4 x faster than classroom training on average. Faster training results in lower costs.
- 4 x more focused than e-learners
- 3.75 x more emotionally connected to the content than classroom learners.

FIRE SERVICE TRAINING

A report produced by the NFPA in 2016 showed significant gaps in training requirements compared to the actual. It provided a frightening statistic that showed: ‘Overall, 50% of departments that provide structural firefighting have not formally trained all of their involved personnel.’ So, what are the issues?

Training is expensive. There is the initial cost of construction of facilities, ability to attend, running costs (including personnel costs) and access. A recent live fire training facility was constructed in Melbourne, Australia for A$108 million. My inquiries indicate that very little is known about the full cost of live fire training. It needs to include capital costs, running costs, maintenance, wear and tear on pumpers, number of staff to run safely, cost of clean up of gear used such a cleaning PPE, cost of getting trainees to central training locations and cost of overtime for participants and back filling to cover vacancies created on shift.

Firefighter training is inherently dangerous. In 2018, 8,175 firefighters were injured in the US during training. There were 11 deaths. Major causes of injury included burns, smoke inhalation, fractures, strains, heart attack and stroke. According to the NFPA, the cost of all injuries to firefighters in 2018 was between $1.6 and $5.9 billion. It was not possible to separate out the costs of injuries in training, but based on the fact that 14% of injuries occur in training, the costs are significant.

Immersive Learning in the fire service

Whilst the concept of Immersive Learning is relatively new the fire service has been using simulation in training for a very long time. In the past the service used available material in burn buildings. These facilities have in the main been replaced by gas-fired props, which are purpose built and costly to install and run. There are many who say the current forms of training no longer represent what occurs on the fire ground.

The following is a quote from an anonymous firefighter as part of research undertaken as part of a NIST report into the use of virtual reality by emergency services:

> *'There is* ***no replacing real experience****. As the number of fires dwindle nation wide, I think our dumbed down hyper sterilized training has become a detriment to firefighters. It is no longer realistic and* ***does not prepare us****.'*

The comment would be strongly supported by many in the fire service. The question could be that fire services are breaching OH&S by not providing training that replicates what they will encounter on the fire ground.

The latest technology provides an additional pathway to learning. I am not suggesting doing away with live fire training but rather advocating for blended learning that takes advantage of today's technologies and using immersive learning to supplement existing live fire training.

A firefighter in PPE experiencing immersive learning with a full range of haptics including the jet reaction from the nozzle.

WHAT ARE THE KEY ISSUES RELATING TO FIRE-SERVICE TRAINING? HOW DOES IMMERSIVE LEARNING ADDRESS THESE ISSUES?

Health and safety

If using virtual learning, there is no exposure of the trainees and instructor to the products of combustion although the trainee can be immersed in a smoke-filled room or exposed to toxic chemicals in the virtual world. Safe to use AFFF with no risk to the trainee. It is possible to expose the trainee to extremely dangerous scenarios that it is not possible to do on a fire training ground (e.g. BLEVE).

Learning outcomes

We learn from making mistakes and this can be done safely in the virtual environment. It is possible to halt the training session and repeat as often as required to achieve muscle memory and instinctive responses. There is also considerable evidence that the outcomes of 'doing' and making mistakes provides a greater retention of knowledge.

Environment

There are no environmental consequences of using virtual learning; no smoke, no runoff, no toxic residue and no waste of potable water even though the scenario may involve the use of materials such as AFFF and other hazardous materials. Training can take place indoors regardless of weather.

Realism

To be effective the scenarios must be based on science and physics and have the look and feel of a real fire, taking into account the types materials burning and the length of pre-burn prior to attack. The amount of extinguishing agent used and the time taken to knock down and extinguish the fire must be consistent with the same materials in reality. The instructor may increase the degree of difficulty to help achieve certain training objectives. These changes can be achieved at the touch of a button.

Cost

The cost of entry to virtual learning is a fraction of the cost of the alternatives.

- It is portable, and the systems are taken to the trainee to train at a time that is convenient to them.
- Eliminates travel time and associated costs such as overtime.
- Reduces the impact of wear and tear on equipment such as fire apparatus, costs of consumables.
- Reduces the cleaning costs of firefighting kit after each exposure to the products of combustion such as container-based training.

Immersive learning is now available for the fire service and can be used for firefighting skills training, incident command and fire investigation. It is up to the fire service to use these technologies to provide realistic training.

A recent advice from the US Fire Administration advised that VR training for the fire service may save lives.

'Train like it is real; train as if your life depends on getting it right.'

This article first appeared in the March 2022 issue of International Firefighter and is reproduced with the kind permission of MDM Publishing Ltd – www.mdmpublishing.com

POSTERS FEATURED IN AFAC CONFERENCE & EXHIBITION 2022

This section displays five informational posters that were developed by SCDF units and submitted to the Australasian Fire and Emergency Service Authorities Council (AFAC) Conference & Exhibition, Australasia's largest and most comprehensive emergency management conference and exhibition.

Development of an Evidence-Based Proficiency Test for Firefighters

SCDF's Professional Development Framework

Mental Health Support for SCDF's Conscripts

Attitudes and Perceptions of Singaporean Paramedics in Mentoring Trainees

Strengthening Resilience: Fitness 4 Programme for SCDF Personnel

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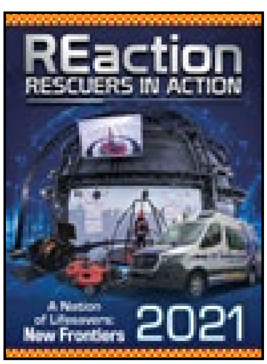

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