REaction

RESCUERS IN ACTION

2018

TOGETHER
A NATION OF LIFESAVERS

TRANSFORMING INTO THE FUTURE

TOGETHER
A NATION OF LIFESAVERS

CONTENTS


SCDF
The Life Saving Force

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REaction

"REaction - Rescuers in Action" is the SCDF's annual technical publication that aims to be a platform to invoke 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 insights and found REaction beneficial to you.

COMMISSIONER'S FOREWORD

As REaction enters its fifth year of publication, it has become an established journal and continues to serve as a professional platform for the sharing of knowledge and experience in the field of emergency and disaster management, both within SCDF and among the larger fraternity of emergency responders.

For SCDF, we continue to pursue our vision to build 'A Nation of Lifesavers' with an emphasis on 'Transforming into the Future'. We launched the electronic version of the 2018 Fire Code in August – in line with our quest to promulgate digital transformation and provide service excellence in the interests of our industry stakeholders. Our overseas standby deployment contingent, known as the Operation Lionheart Contingent (OLHC), has successfully integrated robotics in their operations during the United Nations' International Search and Rescue Advisory Group (UN INSARAG) External Reclassification (IER) exercise. The use of an Unmanned Aerial Vehicle (UAV) and a semi-autonomous load-carrying transporter in the 36-hour gruelling exercise demonstrated our operational edge and readiness towards adopting innovative solutions in our rescue operations. We are proud to share that the contingent was successfully reclassified as a Heavy Urban Search and Rescue (USAR) team this September.

We ran a special edition of REaction earlier this year at our annual Workplan Seminar in April, where it provided a glimpse into the initiatives that SCDF had undertaken in preparation for the future. Since then, our concept of operations continued to be shaped by technological advancements. In this issue, 'Transforming into the Future' is featured as a theme as we seek to address resource challenges ahead, and enhance current solutions to adapt to the ever-changing needs of emergency response.

To all authors and the editorial board, I would like to express my appreciation for your valuable contributions to 'REaction 2018'. I hope the articles featured will not only serve as a useful resource, but will also excite you and rouse relevant interest among our community of lifesavers.

Eric Yap
Commissioner
Singapore Civil Defence Force

EDITORIAL PREVIEW

In view of the aging and shrinking workforce, SCDF believes that the journey of transforming into the future goes beyond merely innovation and technology. People remain at the heart of transformation, and it is only in the hands of people that innovation and technology can flourish.

With the EMS Tiered-Response System as the nucleus of the transformation, SCDF prioritized the upskilling of the responders, and took intentional and progressive steps to upgrade the "heart-ware" of their people. The dual-skilled responders were also entrusted with a novel creation, known as the Fire Medical Vehicle (FMV).

In this article, SCDF describes its quest to prepare for a future-ready workforce. Read on to understand SCDF's approach towards skill transformation among their people. Interested persons who want to learn more about SCDF's vision to curb this long-term challenge can contact the Editorial Board to find out more.

FUTURE-READY WORKFORCE TRANSFORMATION – OUR PEOPLE

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Introduction

Increasing life expectancy and declining birth rates – the "demographic time bomb" is not unfamiliar to many developed countries around the world today. Owing to medical advancements and the "longevity effect", the median age of the world's population looks set to skew high in the years ahead. Singapore is not spared from this phenomenon, as the average life expectancy rate hits 82.9 years and gives it a World Life Expectancy ranking of 4, according to the World Health Organisation (WHO) data published in 2018.[1]

In 2017, our total fertility rate of 1.16 was significantly lesser than the recommended 2.1 for Singapore's population renewal.[2] Beyond 2020, it is projected that the total workforce growth will slow to half of the average of the past 30 years[3], as illustrated in Figure 1.

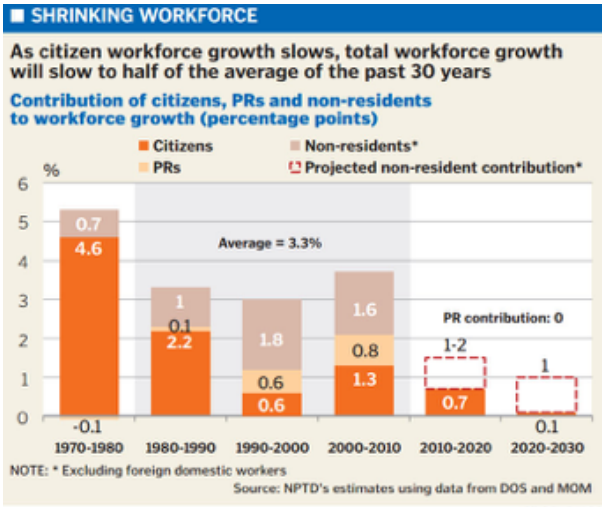


Figure 1: Singapore's workforce growth projections till 2030

Irregularities in age distribution is of no doubt detrimental to a nation's labour market. In the case of an aging population, the challenges extend to providing sufficient and timely medical, health, and nursing care for the elderly.

Impact on Emergency Response

Since 2003, the number of emergency medical calls has increased by about 5% each year. As the core service provider to Pre-hospital Emergency Care (PEC) in Singapore, SCDF plays a critical role in ensuring that the provision of Emergency Medical Services (EMS) is not compromised in view of an aging and shrinking workforce.

A comprehensive study on the future demand of emergency response showed that medical cases are expected to hit a range of 276,000 calls to 356,000 calls by 2025. This is a significant 50% jump in comparison to SCDF's response to 182,502 medical calls in 2017. Fire and Rescue calls are also expected to increase by about 20% by 2025.

It is hence indisputable that the consequences of an aged society will overwhelm current protocols related to emergency response. Acknowledging the fact that demands will soon outstrip resources, SCDF took steps to envision a future-ready and skilled workforce, prepared to curb the long-term challenge of an aging and shrinking population.

Seeding the "Heart-ware" of Transformation

> *"While one machine may be able to do the work of fifty ordinary men, no machine can do the work of one extraordinary man."*
> *– Elbert Hubbard*

To paraphrase Elbert Hubbard, people remain at the heart of transformation, and it is only in the hands of good "heart-ware" that innovation and technology become multipliers.

The seed of skill transformation was first planted seven years ago, where SCDF upskilled firefighters with fundamental emergency medical capabilities to reinforce their EMS counterparts. Following that move, a pilot group of 80 Firebikers were trained to respond to cardiac arrest cases prior to the arrival of the ambulance (refer to Figure 2). The transition to despatch Firebikers for medical calls was not merely confined to the training and equipping of the Automated External Defibrillator (AED). The Firebikers were also coached to manage Next-of-Kin and bystanders at the scene, and a high level of competency was certainly required of these first responders.

Cardiac arrest?

Fire bikes TO THE rescue

They attend to 58 such cases after being fitted with defibrillators

By SHYNA SIM

FIRE bikers from the Singapore Civil Defence Force (SCDF) have responded to 58 cardiac cases after they were equipped with automated external defibrillators in April.

On average, 95 per cent of those cases – 34 in April and 24 in May – were attended to within 11 minutes by these firefighters on motorcycles.

The fire biker concept was introduced by the SCDF in 1998 to help firefighters cut through traffic in the event of a medical call.

But the move to equip them with defibrillators and to train the firefighters to use them was announced earlier this year at the SCDF workplan seminar in April.

Spokesman Leslie Williams said it was aimed at providing the force with a more mobile alternative when responding specifically to cardiac arrest cases.

This, he added, was in addition to the fleet of SCDF first-response paramedics, who respond to medical emergencies on motorcycles.

Citing a case attended to by a fire biker last month where someone collapsed in public, Lieutenant-Colonel Williams said: "The initial role performed by the fire biker was crucial in reviving the subject."

Fire bikes are now deployed from 40 locations around Singapore, instead of just at the island's 14 fire stations when they were first introduced.

A new addition to the fire biker fleet this year are 12 three-wheeler Italian-made motorcycles, which will gradually replace the current fleet of 24 two-wheelers.

"The bikes can weave through traffic and reach incident scenes faster," he said. "Every minute saved is an increased chance of a life being saved, especially in cardiac cases."

Weekly lessons and passing two examinations a year are also required.

The chairman of the National Resuscitation Council, Professor V. Anantharaman, said the addition of defibrillators to the fire bike concept is a real game-changer for first-responders to cardiac emergencies.

Prof Anantharaman, a former head of emergency medicine at the Singapore General Hospital, said very few people who experience chest pains call for ambulances.

"At the moment, there's on average a 10-minute delay before a call for help is made," he said. "That's crucial because chances of survival go down with every minute of delay."

His comments are in line with a survey done by researchers from the cardiac department of the National University Heart Centre Singapore, which found that only one in three patients rolled on an ambulance to get to the hospital in cases of cardiac arrest.

The study of 252 patients found that those who called for an ambulance were treated an average of 81.6 minutes faster, from the onset of symptoms to the time of treatment, than those who did not.

Some doctors, however, felt that there needs to be a greater public awareness of the fire bikers as an option in cases of collapse, chest pains and breathlessness.

Dr Dinesh Nair, a consultant cardiologist at Mount Elizabeth Hospital, welcomed the fire bikes, but said: "I don't think the public is that aware of how the fire bikers can help save their lives."

He suggested that SCDF print posters and speak to grassroots organisations about it. "This could even be tagged on to one of SCDF's campaigns," he said.

ST bysim@sph.com.sg

The new three-wheeler fire bike. These bikes will gradually replace the current two-wheeler ones for the fire biker fleet. These bikes can weave through traffic and reach incident scenes faster than, say, ambulances. PHOTO: LIANE JAZIAH

The automated external defibrillator that SCDF's fire bikers have been carrying since April. These bikers are in addition to SCDF's fast-response paramedics. PHOTO: THE NEW PAPER

Figure 2: Featured SCDF Article in the Singapore Straits Times on 12 Jul 2012

To further facilitate skill transformation, the EMS Tiered-Response System was developed in 2014 with the aim to enhance SCDF's concept of operations in managing the increasing demand for EMS. The system was introduced as an integral part of the SCDF EMS Master Plan 2025, and central to its strategic direction, the Emergency Medical Technician (EMT) scheme and the Fire Medical Vehicle (FMV) were conceived in tandem to buttress the implementation of the system in April 2017.

Unlike its preceding single-tiered operating model where medical cases were attended to on a first-come first-served basis, the tiered-response system adopted a differentiated concept by calibrating response based on acuity (refer to Figure 3). The SCDF Operations Centre was enhanced with the implementation of the Advanced Medical Protocol System (AMPS) to ensure that a robust call-centre triaging system was in place, and appropriate resources were despatched accordingly to the severity of the case. A seamless and effective response model was pivotal to this concept of operations.

CATEGORY OF CASES	EXAMPLES	TIERED-RESPONSE
LIFE-THREATENING EMERGENCIES	Cardiac arrest, unconciousness, active seizure, major trauma and stroke	Highest priority Fastest response Extra resources deployed
EMERGENCIES	Severe allergy, emergency labour, head injury, bone fracture, asthma, elderly with chronic medical conditions and sick children	High priority Fast response
MINOR EMERGENCIES	Cut with bleeding, accident with bruising, swelling, mild injury and persistent fever	Lower priority Slower response *In 2017, SCDF attended to 42,581 minor emergency cases (23.3% of total ambulance calls).*
NON-EMERGENCIES	Constipation, chronic cough, diarrhoea and skin rash	Emergency medical assistance not required Seek treatment at clinics or call **1777** *In 2017, SCDF attended to 11,384 non-emergency cases (6.2% of total ambulance calls).*

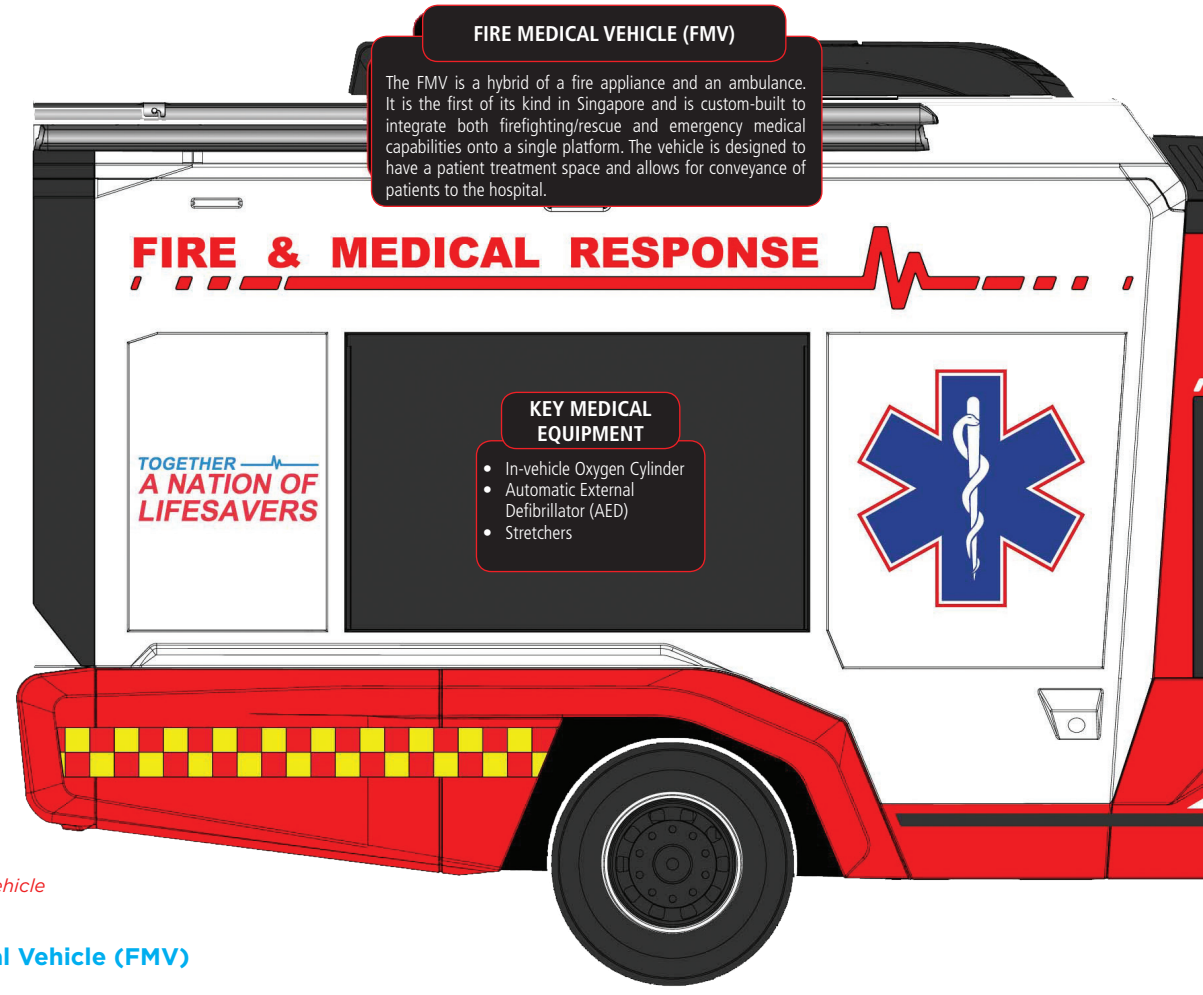
Figure 3: EMS Tiered-Response Framework as of 1 April 2017

Dual-Skilled Responders

Prior to the execution of the EMS Tiered-Response System in 2017, there was an apparent need to expand from the pilot group of Firebikers who were trained to respond to minor medical emergencies and cardiac arrest cases. SCDF formulated a framework to build a pool of dual-skilled responders under the EMT scheme. Fire and Rescue Specialists (FRS) were progressively identified in batches to undergo six weeks of training, in order to acquire a Level 2 certification in medical competency. They were upskilled in both theory and practice to manage medical protocols, such as trauma, acute myocardial infarction, respiratory emergencies, and cardiac arrest. The completion of the training warrant them the proficiency to manage low-to-medium acuity medical cases independently.

Thereafter, the conferred cross-trained FRS-EMTs were deployed for experiential learning. They were appointed to complete a two-year stint with the EMS crew of a fire station, where they would gain ground experience assisting the paramedics in responding to all medical emergencies. At the end of the two-year stint, the FRS-EMTs would return to their Fire Rotas as full-fledged dual-skilled responders.

As the FRS-EMTs possessed both the “heart-ware” for fire/rescue and medical cases, they could be assigned to any emergency appliance to aid in response. FRS-EMTs could turn out in the Pump Ladder (PL) or the Light Fire Attack Vehicle (LFAV) without the ambulance. In the event that there are casualties, their cross-training would allow them to perform initial triaging and stabilisation while waiting for the arrival of the paramedics to commence PEC.



Fire Medical Vehicle

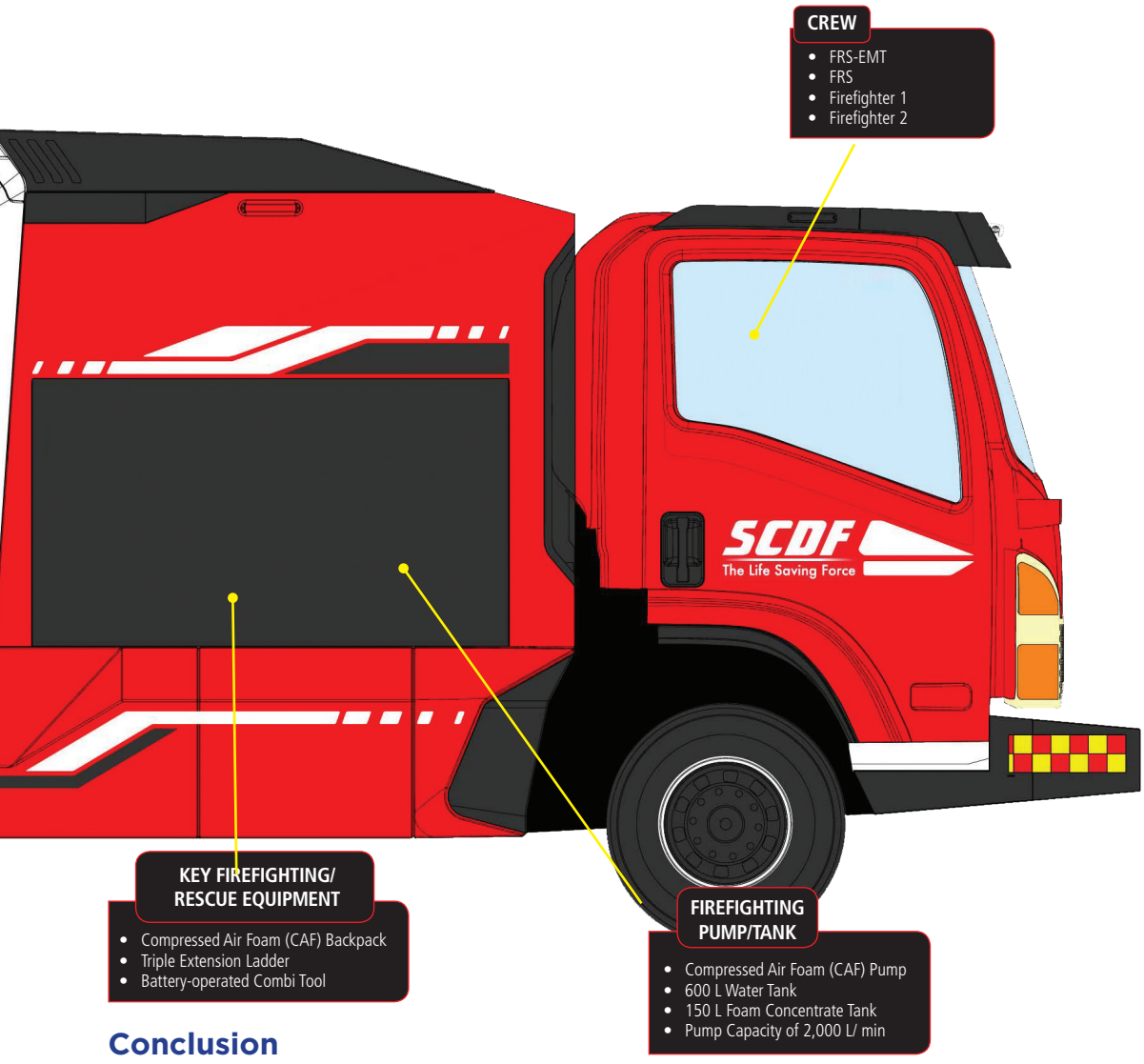
Fire Medical Vehicle (FMV)

Similar in notion to upskill the "heart-ware" of people, the FMV is an upskill of SCDF's "hardware". One key aspect of the EMS Tiered-Response System included the conceptualization of the FMV, which is a hybrid vehicle epitomising the integration of fire and medical response capabilities within SCDF. In other words, the FMV is a physical manifestation of the FRS-EMT amalgamation, and it serves to work alongside the FRS-EMTs in responding to a wider range of emergencies.

The FMV is equipped with firefighting capabilities, such as a fire pump and a water tank. It also contains a patient cabin similar to an ambulance, with the capacity to convey up to two lying patients or three seated patients. FRS-EMTs on board the FMV would be assigned to respond to Priority 3 (P3) medical cases to carry out initial triaging, patient assessment, and life-sustaining medical treatment. If the injuries were assessed to be at least a Priority 2 (P2) case, the FRS-EMTs would serve to stabilise the patient and provide immediate basic life support prior to the arrival of the ambulance.

The first phase of the EMS Tiered-Response System was rolled out in April 2017, and it involved the operationalisation and deployment of 30 Fire Bikes and 6 FMVs with FRS-EMTs at selected bases. Under this phase of the operating model, the FMV was despatched to all industrial and road traffic accidents within the station boundary of the FMV base, as part of the first fleet of responding appliances (together with the Fire Bike, the PL, and the LFAV). At the incident site, the dual-skilled responders equipped with medical competency, rendered medical care while the others attend to firefighting or rescue operations.

The full roll-out of the EMS Tiered-Response System will be executed by 2025. At a steady ideal state, the SCDF's PL, LFAV, Fire Bike, and FMV will be manned by at least one dual-skilled FRS-EMT. The prudence in this calibrated deployment of medical resources serves to address the rising demand for EMS, which is in line with the primary objective of the EMS Tiered-Response System.



Conclusion

A Future-Ready Workforce

SCDF's transformation journey is not bounded by just the mere leverage on innovation and technology. An organisation is, after all, the sum of all her people and what they are capable of. With the genesis of the EMS Tiered-Response System, upgrading the "heart-ware" of responders fits inherently into the grand scheme of managing this resource challenge ahead. Assembling and sustaining a pool of dual-skilled responders translates into a corresponding increase in versatility in the types of incidents one could be deployed to assist. This is in essence an optimisation of SCDF's existing manpower resources. Coupled with the enhanced concept of operations and the personification of the FMV, SCDF is prepared to undertake the long-term challenge of the "demographic time bomb" on emergency response.

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[1] "Singapore: Life Expectancy" https://www.worldlifeexpectancy.com/singapore-life-expectancy

[2] "Singapore's fertility rate at new 7-year low of 1.16: Josephine Teo" https://www.channelnewsasia.com/news/singapore/singapore-total-fertility-rate-new-low-1-16-10002558

[3] "Slower, but quality economic growth over the next 20 years" by Robin Chan, The Straits Times, 30 January 2013

EDITORIAL PREVIEW

Since 1999, the Civil Defence Academy (CDA) has served as the principal training ground for responders. As the needs of the society evolve and become more complex, SCDF's approach to emergency response needs to be frequently reviewed for better positioning and alignment with the ever-changing demographics. The National EMS Training Centre (NETC) – a future medical facility – has been planned to be erected in the CDA Field Training Area in its strife to address Singapore's greying population. The NETC is designed to tap on modern technology and realistic environmental settings, providing a holistic training location for Emergency Medical Service (EMS) personnel to strengthen their competency and boost their confidence in Pre-hospital Emergency Care (PEC). With customised training rooms, the NETC will also facilitate innovative learning, driving EMS personnel to improve on existing medical skillsets and acquire new ones.

This article discusses in detail the features of the NETC, and the collaborations it has established with other healthcare institutions. Interested persons can contact the Editorial Board to find out more about this new development.

NATIONAL EMS TRAINING CENTRE (NETC) – SCDF'S PURPOSE-BUILT PRE-HOSPITAL EMERGENCY CARE TRAINING FACILITY

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CPT William Wu, Senior Instructing Officer, Civil Defence Academy
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Introduction

In 1996, SCDF started its own Paramedic Scheme to operate the EMS. Since the start of the scheme, SCDF has worked with Singapore Armed Forces (SAF) for its paramedics to be trained at the School of Military Training Institute (SMTI), formerly known as the School of Military Medicine (SMM). It is a programme accredited by the Justice Institute of British Columbia (JIBC), Canada.

The demand for EMS services is growing at a rapid rate, with our aging population and with the volume of emergency ambulance calls increasing at a rate of 5% annually. To cope with this growth in demand, there is a greater operational need for frontline rescue crew to be cross-trained as EMTs, to increase the training throughput of paramedics and yet equip our paramedics and Emergency Medical Technicians (EMTs) with higher levels of clinical skills and competency. These measures are inevitable to allow SCDF to continue to save lives and contribute effectively to the healthcare ecosystem in Singapore.

A Pre-hospital Emergency Care (PEC) Steering Committee was set up jointly by the Ministry of Health and Ministry of Home Affairs to manage the provision of emergency medical care in an out-of-hospital setting. SCDF signed a Memorandum of Understanding (MOU) with SingHealth Group on 11 January 2017 to formalise the working arrangement. The MOU, spanning six years, will deepen the collaboration and lead to sustainable improvements in PEC through enhancing education and research collaborations.

Need for Transformation in Training Resources

When the Civil Defence Academy (CDA) was opened in 1999, the training simulators and other facilities were built based on operational requirements in the early 1990s and catered mainly for fire-fighting and rescue training. The EMS facilities which were added on with time are inadequate to cope with the today's training demands, and lack the advantages of advances in simulation training and medical technology.

Today, its training courses are being reviewed to increase the medical competencies of frontline responders, such as through introducing team-based High Performance CPR, and building competencies in essential soft skills such as critical thinking, communication and collaboration, through the use of modern pedagogies.

With the escalating threat of terrorism globally, there have been significant doctrinal changes in the way SCDF operates and an increase in the tempo and realism of peacetime training. For example, In-Camp Training for Operationally-Ready National Servicemen (ORNS) has increased in duration and intensity, placing further demands on the existing training facilities and manpower. There is also a need for training to be able to continue safely even in inclement weather, to maintain the realism of training as well as ensure that trainees' time is spent efficiently.

The National EMS Training Centre (NETC)

To cater to these newly-identified training needs, SCDF conceptualised NETC as part of the CDA Field Training Area (FTA) Redevelopment Project in 2017. With SCDF as the leading pre-hospital provider in Singapore, NETC aims to be an independent national institution, providing sustainable solutions for the increased training volume and recertification requirements for our career paramedics, EMTs, Full-time National Servicemen (NSFs), and ORNS. In collaboration with our partners, NETC will also develop its capabilities in the existing programme, Continuing Medical Education (CME), in pre-hospital care, and continue to train and develop its faculty.

Concept of NETC

NETC will be set up under the CDA FTA Redevelopment Project. The centre will:

- Provide national training at different levels of required competencies to deliver excellent and effective pre-hospital emergency care in Singapore
- Support the infrastructural requirements for the end-to-end training of EMS (from the point of activation of ambulances to conveyance of patients to hospital) under the train-as-we-operate concept
- Leverage on technology to simulate realistic and safe EMS training and enhance the learning experience of participants from all healthcare settings

NETC comprises a Medical Skills Mastery Area, scenario-based Concept Rooms and a scaled-down mock-up of a hospital emergency department.

The trainees will be exposed to Collaborative Team Based Training from pre-hospital to hospital settings to exercise the concept of continuity of care – from the Fire and Rescue-EMT Specialist to the EMS crew, from EMS crew to the hospital staff and from EMS crew to the NS Medical Unit.

The new learning environment is a pedagogical-driven design to facilitate modern learning styles such as scenario-based learning, self-directed learning and peer-to-peer learning.

The learners will be able to progress through the four levels of competency (refer to Figure 1) and the relevant skills will be mapped according to the competency.

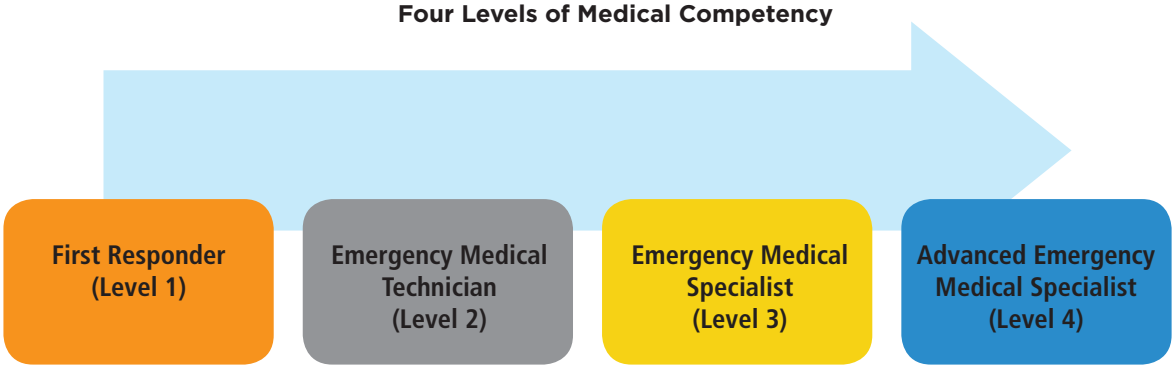

Figure 1: Four Levels of Medical Competency

Enhanced Patient Care Management through Simulated Environment

Part of the NETC will be designed to mimic the complete pre-hospital process from the moment a 995 call is received, to the handover at the hospital. This will be facilitated by high-fidelity patient mannequins, simulated ambulances, mock-ups of various casualty locations (e.g. roadside, HDB flat and elevator) and a hospital emergency department.

The simulated environments aim to reduce the training gaps by exposing trainees to practical difficulties that they would potentially face day-to-day, but are difficult to convey through routine classroom teaching. For example, in the mock-up of a clinical handover area in a hospital emergency department, they would be able to practise proper handing over of cases to the hospitals, and collaboration with hospital staff.

Concept Rooms for Team Learning

In the past decade, there has been vast developments in the area of medical simulations extending to both augmented reality and virtual reality. The existing Simulation Labs (refer to Figure 2) are no longer able to serve SCDF's training needs as current scenarios are confined to a small room. Leveraging on a combination of physical props, medical simulation and augmented reality technology, the Concept Rooms will offer realistic and immersive environments closely mirroring that of the operational scenarios faced by its responders. Scenario-based medical training will replace didactic teaching methods, and will facilitate team-based training and assessments.

A central console system will enable its instructors to provide instructions or scenario-injects through an audio-visual broadcast. The entire learning process can be recorded for review and feedback by the trainees.

Figure 2: The existing Simulation Lab in CDA FTA

Catering to New Generation of Learners

NETC will also feature a Medical Skills Mastery Area that is equipped with individual clinical stations with clinical simulators and interactive media learning content. Trainees will be given learning objectives but will visit these stations independently and practise their clinical core skills on their own. This approach aims to promote the culture of self-directed learning and 'metacognition', where the trainee can actively assess his or her own learning with the help of the interactive media interface. This Mastery Area is planned to allow access beyond office hours for trainees or existing paramedics and EMTs of all levels of seniority to be able to practise their individual clinical core skills as needed.

Conclusion

NETC will facilitate continuous learning for paramedics and EMTs through opening avenues for collaboration with external organisations for research opportunities and academic advancement. Staff will be encouraged to be involved in the development of course curriculum and content, and to develop their skills as instructors and facilitators so that they can continue the learning journey with staff under their charge in their respective units. With these advancements, SCDF, as a key component of the healthcare ecosystem, will be able to further improve the standards of PEC in Singapore.

EDITORIAL PREVIEW

Gamification has seen a massive rise in popularity in many sectors, but particularly in e-learning. SCDF has not excluded this advantage in their approach to training emergency responders. Apart from residential and commercial fires, SCDF attends to less common incidents, such as oil refinery fires and marine fire incidents as well. To offer training for such scenarios, intensive coordination is required as it involves large amounts of resources, manpower, and land space. Inspired by gamification, the Advanced Command Training System (ACTS) was hence developed to allow for high-fidelity virtual-reality training simulation that could depict realistic scenarios in various settings.

Tailored to Singapore's landscape as well as SCDF's concept of operations, ACTS allows trainees to hone their command skills at an individual level in a controlled and risk-free environment. ACTS also allows for validation of response strategies in mitigating various scenarios. The second phase of this system, ACTS2, is currently in use at the Civil Defence Academy (CDA), and includes complex scenarios such as oil tank and marine firefighting. The ACTS addresses the issue of planning and coordination from the perspective of training responders. Feel free to drop the Editorial Board an enquiry if you require any further information on the ACTS.

INNOVATION IN TRAINING & LEARNING – ADVANCED COMMAND TRAINING SYSTEM 2 (ACTS2)

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Introduction

As the national authority for the provision of firefighting, rescue and emergency ambulance services in Singapore, SCDF responds to a variety of scenarios that range from residential, industrial and commercial fires to the rare oil refinery and ship fires. The latter presents a different set of complexities and challenges which require SCDF commanders to be adept in incident management and situation-based decision making.

In SCDF, training for such operations traditionally took the form of table-top and field exercises, however these exercises lacked the crucial element of realism and visualisation of the incident. Additionally, the scope and scale of field exercises are restricted by the availability of site, safety and cost constraints.

CDA presently has purpose-built outdoor simulators such as a 7 metre diameter oil tank and a 10 metre by 10 metre by 3 metre ship simulator to train SCDF officers in oil refinery and marine firefighting, as illustrated in Figure 1. However, they do not simulate the impact of incidents on a larger scale, i.e., incidents that cover a bigger area of operations and require more resources at site. Trainees are not fully tested on command and control due to the lack of a holistic experience and exposure to large scale incidents.

Consequently, there was a need to fully equip commanders with the desired operational competencies given these limitations.

Figure 1: Trainees learning to tackle oil tank and ship fires using the outdoor simulators in CDA.

Virtual Simulation as a Tool for Experiential Learning

The changing demographics of youth today mean that most of SCDF's trainees would have grown up in the digital age and are widely receptive towards simulation and technology based-learning. Educators today are increasingly interested in using game based assessment to support learning. It is believed that students have positive attitudes towards learning with virtual simulation primarily because of its interactive and challenging nature.[1] Virtual simulation is also an effective tool in building an experiential cycle, as it provides a concrete experience, and allows for active experimentation.[2]

Complex virtual simulation includes a diverse gaming environment and scenarios that focus on different situations, learning domains and particular outcomes. By incorporating the interactive and challenging element into ACTS, scenarios can be designed to be progressive, where the level of difficulty can be pegged to the ability of the trainee. Different challenges can be injected in various stages, making training enjoyable while still imparting learning points to the trainee. In this way, ACTS also becomes more flexible, not only simulating worst-case scenarios from the onset, but gradually building up command and control skills through progressive scenarios. It may even be possible to design a desktop or mobile version of ACTS that would empower trainees to self-learn in their own free time.

Blended Learning

ACTS is a key component of the blended learning approach to training in CDA, where it is used to impart learning points together with classroom lessons as well as field exercises. The system satisfies the various styles of learning, i.e. those who learn best through visual, auditory, tactile and kinaesthetic activities.[3] This creates deeper insights, which can help trainees better understand and retain the lessons learnt. Certain scenarios in ACTS, such as the Chemical Plant and Marine scenarios, are a replica of real-life simulators at CDA. With this, trainees will be able to study the doctrine and case studies in the classroom, practise the doctrine and worst-case scenarios in ACTS, and finally undergo their field exercises with the simulators (refer to Figure 2).

Development of ACTS

SCDF leveraged on innovation and technology to enhance the training of its officers. In particular, simulation technology, whose advancement in the last decade has reduced the cost of developing such systems and expanded the area of their usage.

In January 2010, the ACTS team began the development of a software that aimed to meet the following requirements: This simulation software has to allow instructors to create large-scaled scenarios with ease; provide a VR environment which allows trainees to move freely around the incident scene and finally, the software has to be able to respond to the commands and decisions made by the trainee mitigating an incident. In March 2011, the first prototype of the innovative simulation software was completed.

Figure 2: A container ship on fire as seen from the view of a Rota Commander on board the Marine Firefighting Vessel (MFV).

By March 2012, the first generation of the in-house ACTS was implemented at CDA. The ACTS is a training simulator that utilises 3-dimensional VR programmes to immerse trainees in fire-fighting and rescue scenarios for incident command training for frontline commanders at the fire station. ACTS offered considerable depth and dimension in command and control training through the different permutations of 3 fire-fighting scenarios i.e. residential, commercial and industrial premises. The operational rigor helped in the honing of decision-making skills in stressful conditions within challenging operational scenarios.

Given its proven potential, SCDF developed additional operational scenarios (modules) in 2 separate phases to enhance the scope of ground and senior commanders' training with the existing platform. The two scenarios are namely oil refinery and marine fires. The improved system, named ACTS2, was commissioned at the end of 2016. The ACTS team represented SCDF to work with Home Team Academy in the development of the Home Team Simulation System (HTS2), a highly customized system that enables commanders across Home Team Departments to train in a multi-agency joint incident management and strategic operational decision-making exercise. HTS2 is an event-based simulation that focuses in cultivating synergy in joint operations and tactical incident management.

Breakthrough Features of ACTS2

The new ACTS2 comes with several breakthrough features which allow it to be an enabler to enhance the learning and training experience of trainees (refer to Figure 3).

Figure 3: ACTS2 is an enabler to enhance trainees' learning.

Single and Multi-player Exercise Mode

ACTS2 comes equipped with a 140° panoramic screen for the Ground Commander (refer to Figure 4), scalable sector commanders' consoles (refer to Figure 5), as well as a four metres by two metres large video wall (refer to Figure 6) which serves as a realistic audio-visual stimulus to provide for an immersive experience that replicates the incident site. Figure 7 shows a typical set-up of ACTS2 in CDA.

Figure 4: 140° panoramic screen for the Ground Commander provides an immersive experience.

Figure 5: A sector commander console, located in a separate room. The number of consoles can be multiplied depending on the exercise objectives.

Figure 6: A 4m by 2m large video wall used to conduct briefing and debriefing sessions. With the playback feature, specific instances in the simulation can be shown during debriefs.

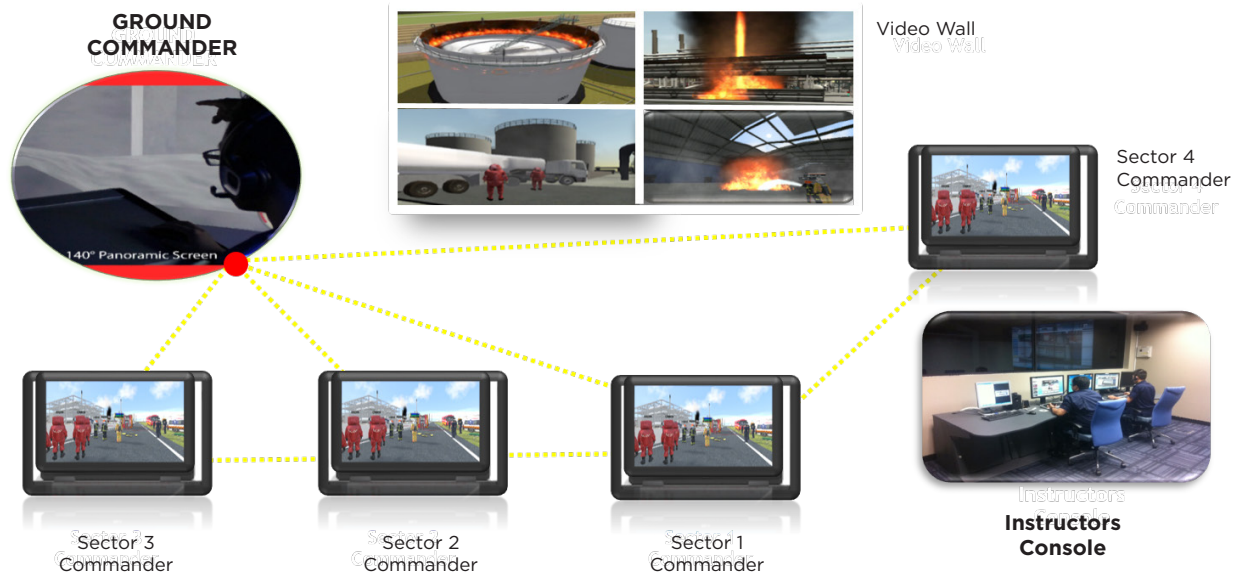

Figure 7: An overview of the ACTS2 set-up.

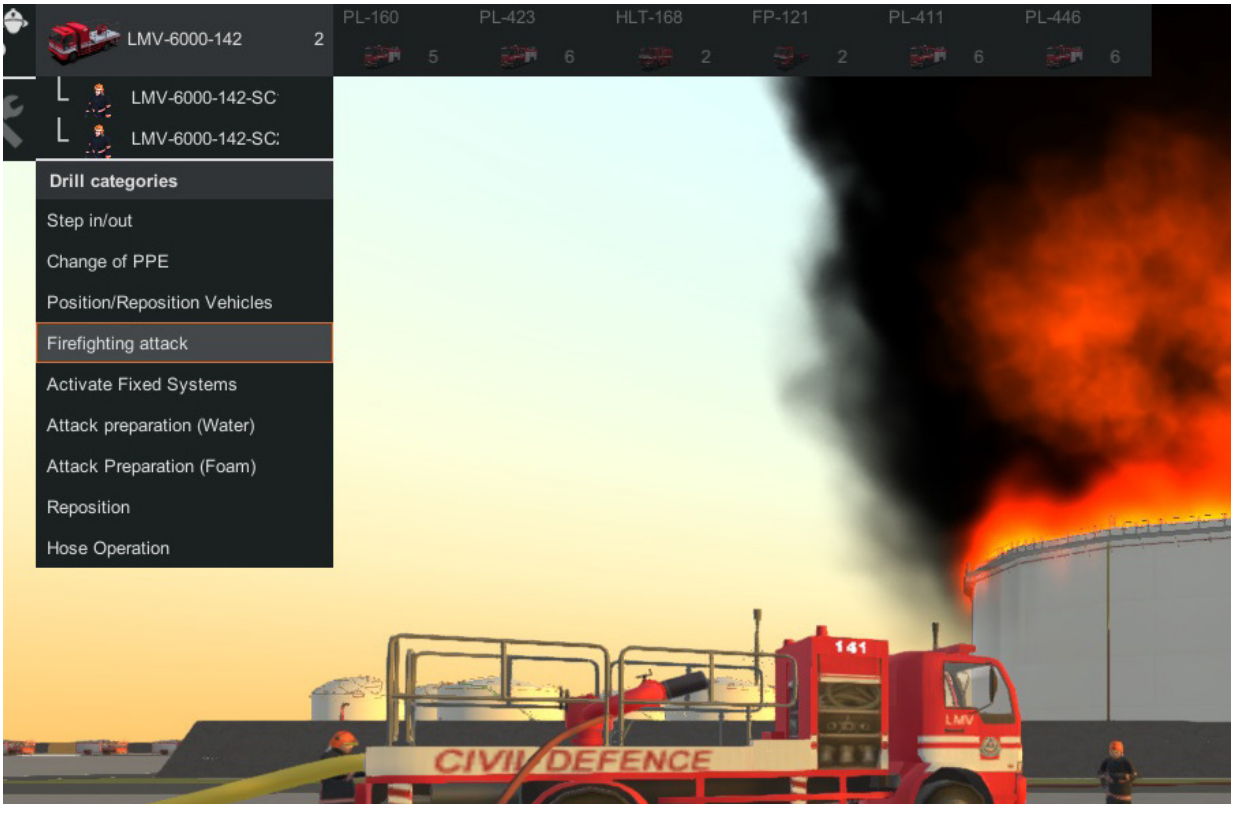

Figure 8: Logic drills such as firefighting actions can be activated by via drop-down lists.

Drill Logics for Deployment of Drills

ACTS2 is incorporated with more than 100 logic drills which is modelled after SCDF's land and marine firefighting and rescue (refer to Figure 8), as well as hazardous materials (HazMat) mitigation drills. This is a one-of-its-kind capability which allows trainees to select specific actions they want to tackle a specific situation.

One of the main features of ACTS2 is that it allows instructors to create challenging scenarios easily. Should an instructor feel that a particular actual incident would make a good case study, the instructor is able to recreate the incident in ACTS2 (refer to Figure 9) with ease. This gives trainees the opportunity to exercise their command and control skills based on a real-life incident. They would also be able to experience the difficulties that were faced by the commander who responded to that incident.

Figure 9: A comparison between an actual incident SCDF has responded to (left) and a simulated incident in ACTS2 (right).

Full Video Playback of Instructors' Helicopter View and Trainee's Perspective for After-Action Review

ACTS2 is able to record up to six screens at a single time which can be used to review the actions of trainees after the exercise. The recordings can show an instructor's helicopter view and the trainees' perspective and played back in the large video wall to provide trainees a complete and fruitful review session (refer to Figure 10).

Figure 10: Recording and playback feature of ACTS2.

A typical exercise session is shown below (refer to Figure 11):

Figure 11: Conduct of a training exercise using ACTS2.

Figure 12: Smoke from a fire being subjected to prevailing wind conditions as set in ACTS2.

Realistic Logical Models for Exercise Validation

The second important feature of ACTS2 lies in its realism. The built-in physics engine enables fire, smoke, and HazMat to behave realistically in this dynamic landscape. These elements are able to react according to the weather that can be customised in ACTS2 – which is a big consideration factor when mitigating an incident (refer to Figure 12).

ACTS2 also offers a feature to track consumption of resources and hydraulic pressure i.e. equipment and extinguishing agents, health and fatigue levels, pressure loss (refer to Figure 13). Trainees can make use of decision-making tools such as gas detectors and thermal imagers that are available in ACTS2 when approaching both fire and HazMat incidents. These tools are programmed to respond accordingly to the hazards that are placed in ACTS2 (refer to Figures 14 and 15).

Figure 13: Realistic simulation models of ACTS2.

Figure 14: A gas detector showing a reading of 25 parts per million as the trainee (in first person view) approaches the chemical plant.

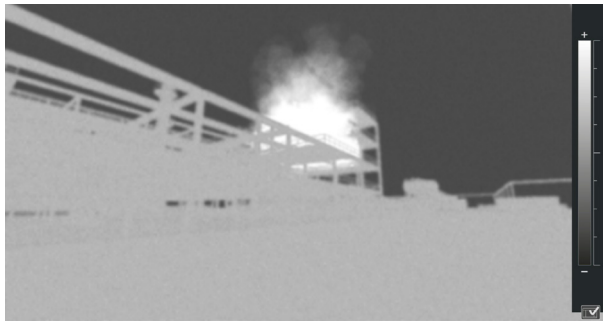

Figure 15: Thermal imagery from the in-built thermal imaging camera in ACTS2.

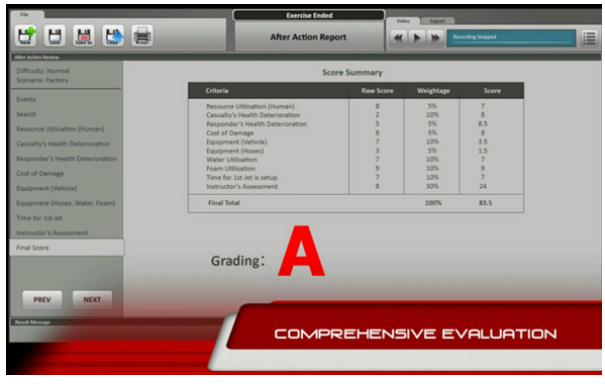

Figure 16: Automated grading of ACTS2.

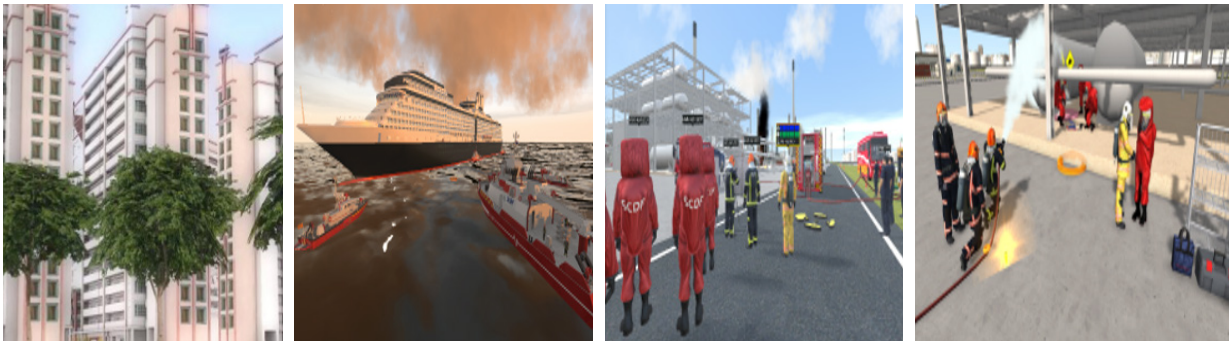

Figure 17: Simulated scenarios are based on actual Singapore infrastructure and visualisations tailored according to SCDF context.

Ultimately it is the ease and flexibility of creating challenging scenarios that make ACTS2 a very useful tool for training. These large-scale simulation exercises can be conducted in a risk-free environment, and trainees are encouraged to formulate new strategies and experiment with various equipment and tactics.

Automated Grading of Trainee's Performance Based On Mission Objectives

To aid instructors in keeping track of the trainees' performance throughout the exercise, ACTS2 provides automated grading of his/her performance based on the mission objectives (refer to Figure 16). This means that the instructors are able to fully focus on the trainees' progress over the course of the exercise without having to keep score separately.

Customisation to Local Terrain and Resources

One of the principal considerations when developing ACTS2 was to replicate its simulated scenarios based on actual buildings and landscapes in Singapore. All visualisations, models and drills are also tailored according to the uniform, appliances, incident command structure and standard operating procedures of SCDF (refer to Figure 17). The complex tasks functionalities in ACTS2 are also aligned with SCDF's Standard Operating Procedures, such as the conduct of the Appreciation of Situation; communication with the SCDF Operations Centre; the sectorisation of areas, matching of tasks and resources, resource management, prioritisation of tasks and command and control actions.

Conclusion

By providing a highly realistic virtual reality environment, ACTS2 augments existing training frameworks to minimize the gap between training and reality. In scenarios involving HazMat, oil refinery and marine firefighting, where limited operational experience can be built up due to the scarcity of such incidents, ACTS2 allows commanders to continuously hone and sharpen their command and control through repeated practices in the virtual world. By increasing SCDF commanders' exposure to a greater variety of complex and large-scale incidents, ACTS2 will prepare them to face any situation competently and confidently, thus strengthening the community's confidence in the Home Team to keep Singapore safe and secure.

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EDITORIAL PREVIEW

Emergency responders work in an environment which necessitates quick thinking and physical exertion. Faced with the challenge of maintaining service standards, especially with manpower constraints and an increase in operational demands, it is important for SCDF to discover new and effective ways to optimise responders' performance without compromising their well-being at the incident site.

This article introduces the Emergency Responders Fitness Conditioning and Enhancement Lab (ExCEL). Located at the Civil Defence Academy (CDA), this facility aims to be the centre for research, development, and education studying the physiological and psychological aspects of emergency responders during training and operations. ExCEL has since embarked on trials to enhance training and operation efficacy in SCDF. The article will also feature the review of the Breathing Apparatus Proficiency Test (BAPT) and the nutrition program implemented at CDA. Do contact the Editorial Board if you are interested to find out more.

EMERGENCY RESPONDERS' FITNESS CONDITIONING & ENHANCEMENT LAB (EXCEL) – USING SCIENCE & TECHNOLOGY TO ENHANCE RESPONDERS' PERFORMANCE

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Introduction

The Civil Defence Academy (CDA) is the premier training institution for the SCDF in training, developing and equipping our emergency responders with the necessary skills and knowledge to adequately prepare them for real operations. The training in CDA exposes them to a plethora of training regime where they are pushed beyond their limits in order to vastly improve their physical capabilities and mental resilience.

With the rapid development of technology in an ever changing operating environment, CDA envisions a centre for Research and Development (R&D) to enhance responders' performance not only in operations, but training as well, aligning with SCDF's Transformation Vision of 2025.

The technology available today has not taken over the role of a human firefighter in its entirety. Firefighters still play a vital role in a successful firefighting and rescue operations. With shrinking manpower numbers and the fact that humans are irreplaceable even with advanced technology, the need to optimise each emergency responder prevails.

The Emergency Responders' Fitness Conditioning & Enhancement Lab (ExCEL) undertakes research and trials to; (1) Review and develop training regimes and proficiency tests using evidence based findings, (2) provide an engaging and immersive training environment for emergency responders, (3) conduct comprehensive evaluation of responder performance, taking into account quantitative and qualitative indicators of human biomechanics, cognition, psychological attitudes and behaviours and (4) conduct R&D of emergency responders.

To achieve the above outcome, ExCEL will look into different areas to enhance physiological and psychological response of an emergency responder during training or operations. ExCEL's main focus will be; (1) Strength and Conditioning, (2) Rehabilitation and Injury Management, (3) Thermal Physiology, (4) Nutrition, and (5) Emergency Leadership and Resilience Behaviours (refer to Figure 1).

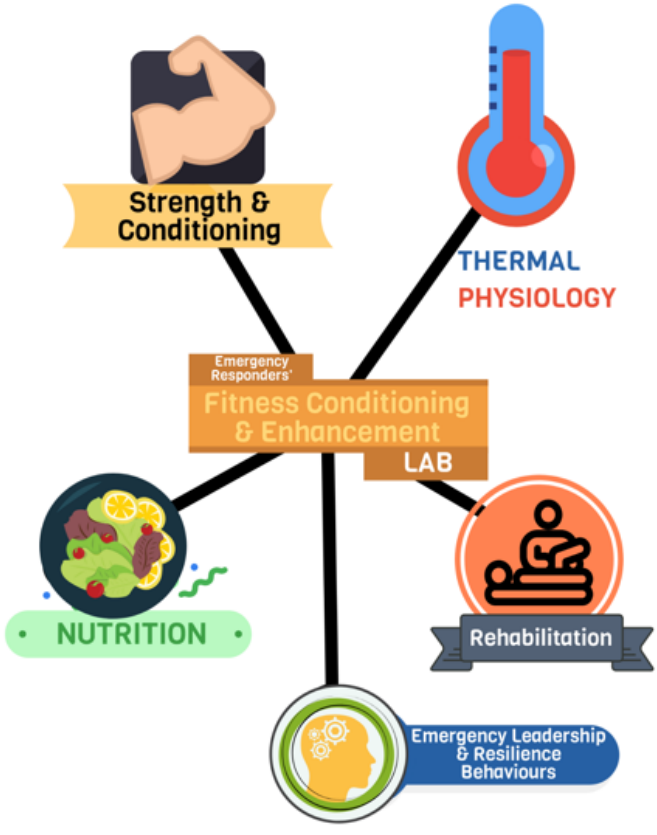

Figure 1: Areas of focus for ExCEL

Strength and Conditioning

At present, it can be said that the functional movements in the training regime will improve the fitness and strength of our future emergency responders. However, little emphasis has been given on muscle development, its progressive build-up, recovery and the means of quantifying it. In addition to the 20-kilogram load of the full Personal Protective Equipment (PPE), emergency responders are required to perform Rescue and Suppression (R&S) and Rescue and Evacuation (R&E) activities which place tremendous physiological stress on the emergency responders. Studies and subsequent development of programs to work on strength and conditioning may lead to an improvement in overall fitness and performance.

Rehabilitation and Injury Management

During prolonged firefighting operations, emergency responders are repeatedly re-deployed upon replenishment of their emptied Breathing Apparatus (BA) cylinders. However, there are no existing scientific parameters at present to determine the fitness or fatigue level of the responders and assess their suitability to be re-deployed. Only visual or verbal assessment are conducted by the commanders. This may lead to unwarranted injuries and affect ongoing operations. This also applies to the trainees to avoid over-training and the inevitable early onset of injuries. With proper rehabilitation to facilitate recovery, both during and post operations as well as during training, the risk of sustaining injuries will be minimised.

Thermal Physiology

Efforts have been put into profiling key physiological parameters (heart rate, core and skin temperature) into a Physiological Strain Index (PSI). The PSI is an index which could account for heat strain originating from both endogenous heat production and exogenous environmental stressors. This would be essential for the objective evaluation of training efficacy and to optimize our trainings and simulations according to local weather conditions. This also involves providing a high degree of fidelity between the training regime and real operations. In the near future, commanders and instructors will be able to have a system that can help them make accurate quantitative decisions to re-deploy manpower or to continue pushing the limits of the men.

Nutrition

Nutrition will also be studied to enhance emergency responders' performance, sustenance during training and accelerate recovery. After a high intensity training, the body is naturally left dehydrated, drained of fuel, and broken down. The body is in a stressed state, and the proper blend of nutrients can jump-start the body's recovery process.

Emergency Leadership and Resilience Management

Appointing the right leader is key to enable responders to deal with challenging and prolonged incidents effectively. Psychological tools can be developed to help select and develop potential leaders to lead their teams and respond to critical incidents. Leaders can also be put through psychometric tests, simulated role plays and exercises to develop their situational awareness and decision making skills. Coaching and debriefing for leaders will also be incorporated to further enhance their leadership traits. In the area of resilience management, ongoing research and data collection can be performed to measure responders' stress levels, mental readiness and morale during prolonged and challenging operations. The use of coping strategies, mental preparation and stress inoculation packages and their effectiveness can be tested for different groups of responders. To facilitate recovery, behavioural skills such as positive visualisation and tactical breathing can be taught to responders to overcome fatigue and stress better.

Current Research Programs

BAPT Study

A Breathing Apparatus Proficiency Test (BAPT) study was undertaken to assess the validity of the current six BAPT test batteries, namely (1) BA Donning, (2) Running Belt Ergometer (treadmill), (3) Endless Ladder, (4) Impact Machine, (5) Bicycle Ergometer and (6) Maze Orientation. A total of 80 firefighters participated in the study. The participants underwent a series of tests, primarily one that involves measuring maximum rate of oxygen consumption ($VO_{2\,max}$) and maximum heart rate (HR_{max}). The average $VO_{2\,max}$ and HR_{max} were expressed in percentage points for BAPT test batteries in Figure 2 and Figure 3 respectively. Based on past literature, fire fighters commonly work between 60 and 80 % of their $VO_{2\,max}$ [1] when suppressing fire and the heart rate (HR) levels of fire fighters performing fire suppression tasks for a substantial period of time were 80% of HR_{max} [2] and above.

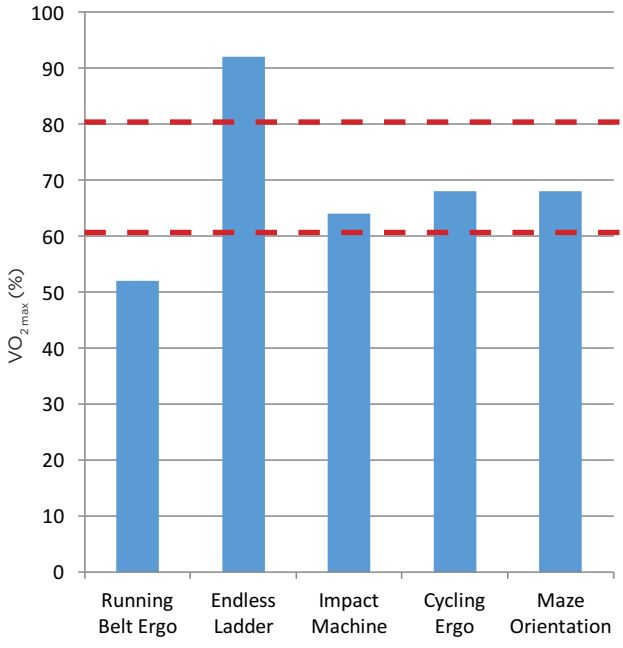

Figure 2: Average $VO_{2\,max}$ expressed in percentage

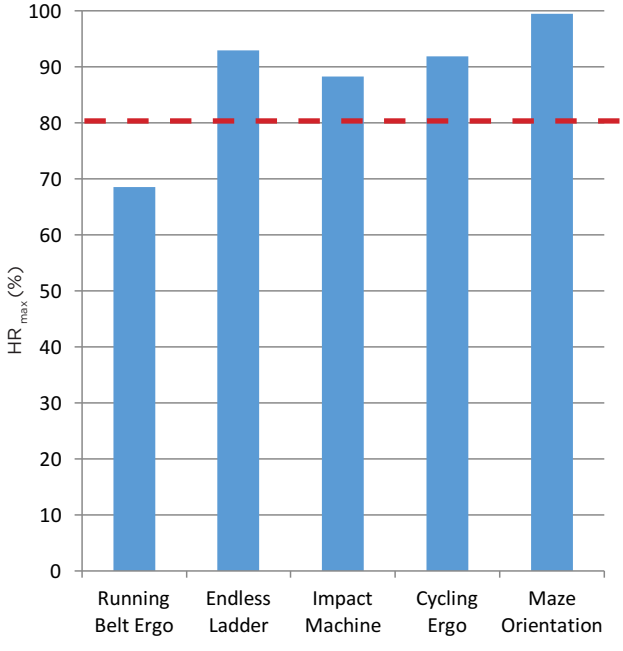

Figure 3: Average HR_{max} expressed in percentage

Subsequently, ExCEL followed-up with the review of BAPT test batteries. A pilot phase was conducted consisting of two stages. Stage one involved conducting the beep test to determine $VO_{2\,max}$ (refer to Figure 4) and maximum heart rate HRmax with a wearable sensor (refer to Figure 5). Stage two involved the proposed BAPT format revision which consisted of six stations, namely; (1) BA donning, (2) Stair climb with load, (3) Hose pulling, (4) 20-metre ladder climb, (5) 43-metre maze with obstacles and (6) 20-metre casualty drag. This is in line with the objective of ensuring that the test that responders undergo is functional and one which elicits similar response to the demands of an operational turnout.

Figure 4. Beep test to determine $VO_{2\,max}$

Figure 5. Wearable sensor to determine HR_{max}

The results showed that during the proposed BAPT format, the participants heart rate increased progressively and remained above 80%. These results were encouraging and in addition to being a functional-oriented test, the proposed format was able to elicit physiological response similar to that of the real operations.

The trial will continue with larger number of trial participants with different demographics to further validate the current results. The implementation of a new BAPT regime will affirm ExCEL's objective to enhance training based on evidence based findings

Nutritional Intake

Currently firefighting trainees are provided a daily caloric intake of 3000 kcal over 4 meals (breakfast, lunch, dinner and supper). Reduced carbohydrate stores in the body and blood glucose is related to the feeling of fatigue and the inability to continue to perform optimally.[3]

Course Commanders have also noticed that at the end of each course, while the trainees were lean, they have less muscle mass as compared to firefighters overseas. This prompted the ExCEL team to undertake a nutritional trial to investigate the optimal calories intake and rate of frequency for firefighting trainees and eventually, operational firefighters.

The aim of the trial is to determine if increasing the daily caloric intake over more meals per day will assist in muscle gain. 200 trainees went through a 10-week trial where each trainee will be given two energy bars per day. The energy bars were to be consumed during two time periods, between breakfast and lunch, and between lunch and dinner.

The trainees had their weight, girth, and a 4-point skinfold measurements taken before and after the trial. Girth measurements were taken at four sites: upper arm, thigh, calf and chest. The 4-point skinfold measurement was used to determine body fat percentage using the equation by Durnin and Womersley.[4]

Post-snack survey also showed that 80% of the participants felt the snack motivates them during intense training. 86% of participants also felt like they had more energy to carry on with training when they were provided with the snack.

The results are preliminary and ExCEL will continue to find ways to quantitatively determine what our responders need. Future studies will look into calculating the energy output of trainees and responders to determine how and when they should eat. Precise test will be conducted to measure the body composition instead of using the current 4-site skinfold test. Some examples are the 3-Dimensional body scanner or dual-energy X-ray absorptiometry (DEXA).

Conclusion

While we continue to uncover the latest in firefighting technology, we should not overlook the training efficacy of our emergency responders in terms of response, performance and recovery. ExCEL's approach can be summarised as having an integrated approach to responder performance. ExCEL will be able to cater to individual-specific training needs and enhance every emergency responder to perform better, faster and longer than ever before.

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EDITORIAL PREVIEW

As much as saving lives is pivotal in an emergency, it is significant to also care for responders. Stress faced by responders during an emergency response can result in heat-related disorders, and deterioration of operational capabilities. To better protect responders, physiological status monitoring systems in the form of wearable technology should be introduced for continuous monitoring of work strain levels. With the ability to track an individual's work strain level, it gives commanders and trainers the ability to detect early signs of heat stress and provide prompt intervention. This inherently gives responders the assurance to operate in emergencies too. When applied to training, these wearables also allow individuals to achieve their optimal performance range.

In this article, the prototype Heat Strain Monitoring System developed by DSO National Laboratories for use in emergency response situations is elaborated in detail. SCDF is honoured to work with DSO National Laboratories on this article, and the Editorial Board hopes that you would enjoy this article.

OPTIMISING FIREFIGHTERS' PERFORMANCE WITH WEARABLE TECHNOLOGY & PREDICTIVE DATA ANALYTICS

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Introduction

Firefighters need to perform physically demanding tasks while enduring intense heat during firefighting scenarios. Heat generated by the body, compounded by ineffective heat dissipation due to the presence of firefighting protective ensemble, can result in increased heat strain in the body.[1] This results in an elevation in the body's core temperature (T_c). Heat strain, if left unchecked, may lead to adverse health effects, including unconsciousness and cardiac arrest. High T_c is a reliable predictor of heat-related disorders[2] and the ability to accurately monitor this parameter could help reduce the risk of heat injuries for firefighters working on the fire ground.[3] Furthermore, while various strategies can be harnessed to combat heat strain, the ability to monitor individualised T_c is expected to further optimise heat management of firefighters.[4][5]

Multiple Tc measurements, when composited into a heat strain index, can reveal the thermoregulatory responses of a working individual. As this information is indicative of the individual's thermo-physiological strain and endurance, it can be used by instructors and commanders to vary the training intensity and work limit for firefighters, thereby optimising training effectiveness while balancing fitness level and operating environment demands. One suitable heat strain index is the physiological strain index (PSI).[6] The PSI is calculated based on heart rate (HR) and T_c, and describes the combined cardiovascular and thermal strain on a scale of 0–10. Several studies have supported the validity of the PSI in its ability to distinguish between different levels of exercise intensity, including one that differentiated the levels of physiological strain for firefighters in personal protective equipment.[7]

At present, accurate and continuous measurement of T_c is possible via mainly invasive approaches, e.g. rectal or oesophageal probes or ingested telemetry capsules. However, the invasive monitoring of T_c is often impractical for a host of reasons including acceptance, invasiveness and cost. While surrogate, non-invasive measurements that estimate T_c, such as tympanic, aural, forehead, or axilla temperature, may be suitable for field deployment, associations between these estimates and T_c are poor and erratic.[8] In addition, these approaches provide T_c measurements that are observable by the individual only. As a consequence, remote monitoring of a team of trainees by the commander, instructor or medic is not feasible.

To provide a viable alternative to invasive approaches for monitoring of T_c and PSI, DSO National Laboratories is developing a non-invasive physiological status monitoring system (Heat Strain Monitor, HSM) for real-time continuous prediction of thermo-physiological strain of soldiers. In this article, the key components behind the HSM, and discuss the anticipated impact and role of physiological monitoring and wearables technologies for assessing physiological strain and enhancing performance of firefighters.

The Heat Strain Monitor (HSM) System

The HSM is a networked system comprising wearable sensors. It has a predictive analytics algorithm that calculates Tc from sequential HR and surface skin temperature (T_{sk}) measurements available online from each user's wearable sensor, wireless data link, and local and remote monitoring stations to inform the thermo-physiological strain of personnel (refer to Figure 1).

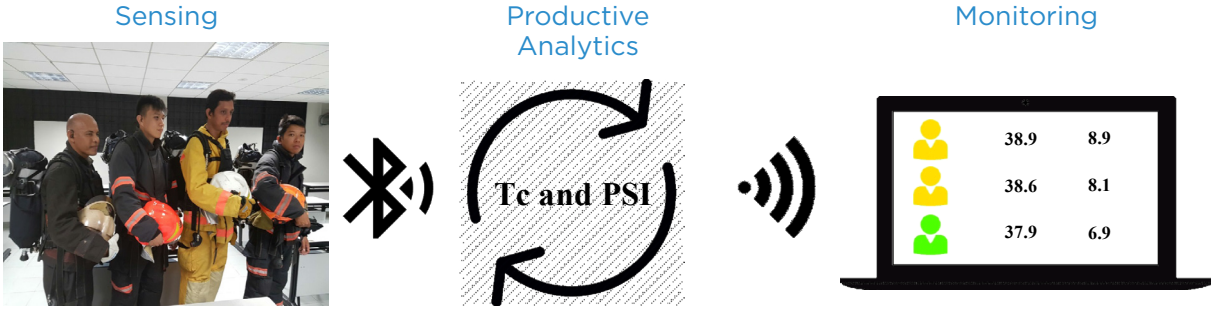

Figure 1: Overall architecture of the Heat Strain Monitor.

a. Wearable Body Sensor

Each trainee will put on a wearable body sensor that is capable of sensing and transmitting HR and T_{sk} continuously. From physiology, both HR and T_{sk} are closely related to work and heat stress, and therefore may be analysed to estimate T_c. Serial HR measurements contain information about heat production[9] and heat transfer since HR is related to skin perfusion.[10] Similarly, because heat can be conducted from the deep tissues to the skin, an increase in T_c can lead to an elevation of T_{sk} over time.[11] While the HSM is currently being developed for integration with the Equivital EQ02 LifeMonitor sensor suite (Hidalgo Ltd, Cambridge, UK), it is flexible enough for interfacing with other commercially available wearable activity trackers that provide reliable physiological measurements.

b. Predictive Analytics Algorithm

The predictive analytics algorithm uses time series observations of HR and T_{sk} to 'track' T_c over time.[12] In particular, the algorithm calculates T_c by understanding how T_c changes over time and the most likely T_c for a given set of HR and T_{sk} observations. HR and T_{sk} are physiologically meaningful and convenient observations of the expected T_c since they contain information about heat production and heat transfer, and can be measured easily using wearable sensors. When tested against T_c measured during military high intensity foot march tasks, the algorithm produced a small mean bias (0.03°C) and root mean square error (0.24°C). Figure 2 shows individualised comparisons between T_c measured using an ingestible thermometer capsule and T_c calculated using the predictive analytics algorithm.

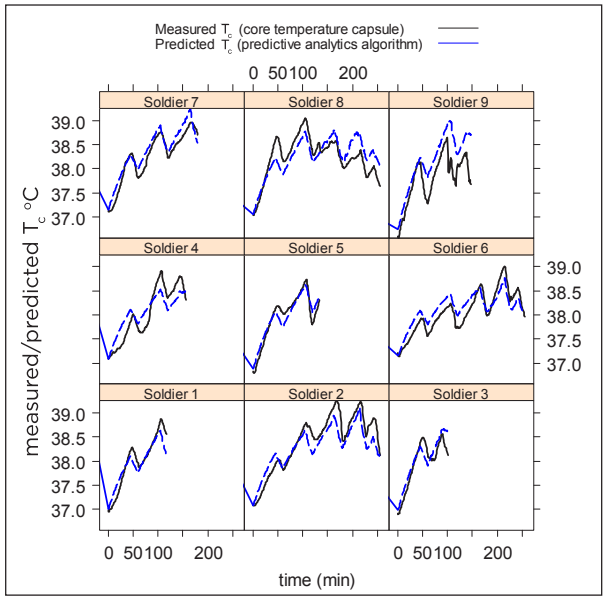

Figure 2: Comparison between T_c measured using an ingestible thermometer capsule and T_c calculated using the predictive algorithm in nine military subjects across a route march (up to 16km) in full battle order configuration.

c. Local and Remote Monitoring Stations

Time continuous values of the predicted T_c and PSI are displayed on the local (smartphone) and remote (commander dashboard) monitoring stations, with each user's local station transmitting physiological strain data wirelessly to the remote station. T_c values obtained can be compared against a clinically accepted threshold for heat injury[13], e.g. 39.5°C, in order to determine an user's likelihood for heat illness in real time. In the HSM, thermo-physiological monitoring is implemented using a "traffic stop light" system, with "green", "yellow" and "red" indicating that he is operating at below, near and above the safe T_c threshold.

Figure 3 illustrates representative screen shots of the local and remote monitoring software with both T_c and PSI displayed.

(A) **(B)**

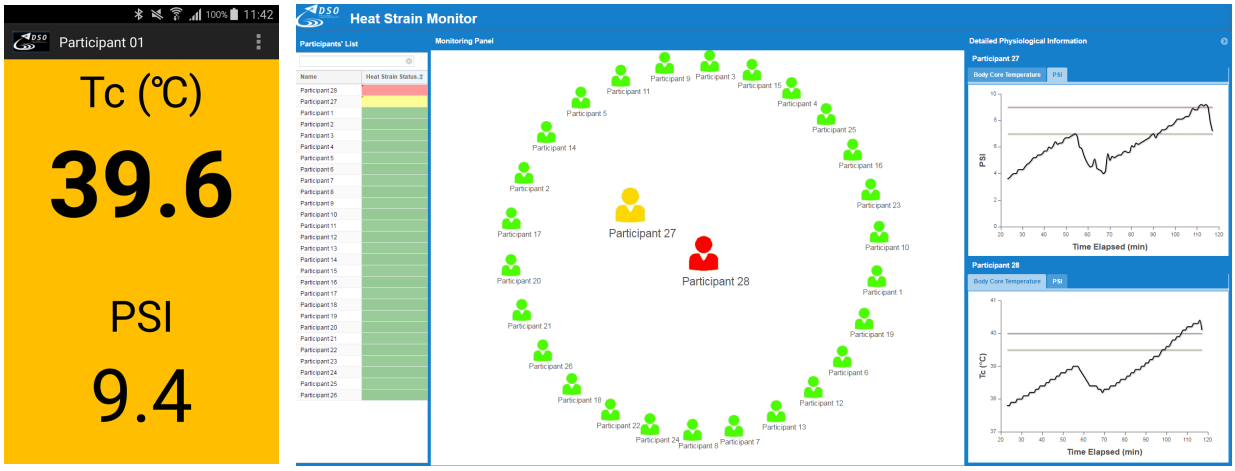

Figure 3: Screen shots of the local (A) and the remote monitoring (B) software with assessment of individualised thermal work strain. For remote monitoring, alerts for individuals in the "yellow" or "red" zone will be heightened for greater emphasis to the commander, instructor or medic.

Application of HSM

The HSM is well-suited for assessing thermo-physiological strain levels of firefighters in operational and training settings. Encapsulated firefighter suits, which offer protection, have the unintended consequence of allowing firefighters to operate for longer time periods. Current metrics for the amount of safe working time in firefighting operations is based on estimates of ambient temperature, workload and exposure, which are prone to estimation bias and ignore the between-trooper variability in physiology and physical fitness level. On the other hand, the HSM provides an approach to monitor T_c and PSI of every firefighter in the fire ground – objective information either empowering the firefighter to stay in longer to finish a job or warning the firefighter to exit sooner. Besides allowing the individual trooper access to thermo-physiological strain information, with network connections, leadership and medical staff can also have remote access to the physiological status of deployed personnel in real time. Furthermore, the HSM may also be useful in guiding the implementation of additional fire ground strategies such as shift tasks and rehabilitation. Overall, the HSM holds out the promise to reduce heat-related illness and enhance operational outcomes on the fire ground.

The HSM system can also be a valuable tool for training of firefighters. Due to the high intensity nature of training drills and self-imposed psychological pressure to continue to push harder even if the individual is aware of feeling unwell, trainee firefighters may ignore early signs of heat-related illness. Therefore, providing real-time monitoring T_c of each trainee and an alert to situations requiring attention could provide a critical early warning of potentially dangerous levels of heat stress and overexertion during training. Additionally, PSI values depict how hard an individual is working during training. Such information could be used by instructors to adjust training intensities in order to maximise training returns. In the same light, T_c and PSI profiles that are accrued over multiple cohorts of trainees can progressively guide the implementation of training optimisation strategies and revision of work-rest cycle standards. This would allow the increase of training effectiveness with full visibility of trooper safety over time. Lastly, by quantifying in relevant environments the level of physiological strain that trainees can expect to experience during training and actual fire service duties, trainees would have a better awareness of the importance of physical conditioning. Such data may motivate trainees to train harder and improve fitness levels, which translates to less training injury and academy attrition rates and enhanced training outcomes.

Two immediate tasks need to be undertaken before the HSM is ready for deployment. First, the predictive analytics algorithm has to be adapted to calculate T_c and PSI in firefighters. Adaptation of the algorithm will require representative sets of thermal work strain data to be measured from firefighter trainees in appropriate training exercises. Second, field testing of the HSM should be conducted in relevant training exercises. These trials must validate the wearability of the HSM as well as functionality of its sensors, signal and programming.

Wearables for Training Optimisation

In order to meet the unique physical demands of firefighting and to perform firefighting in a safe manner, firefighters must be physically fit. At present, trainees undergo a standard programme in order to attain the desired fitness level for completing the course and for passing the required proficiency tests, e.g. the Individual Physical Proficiency Test. However, due to between-subject differences in physical fitness and motivation levels, trainees may respond and adapt differently to the training programme even if they undertake the same activities. This implies that not all trainees will experience the same level of training stress and require the same amount of recovery time. As a consequence, trainees may experience multiple episodes of under- or over-training, which could lead to suboptimal training and overuse injuries.

Besides quantifying thermal work strain, wearable technologies can be used to monitor physical fitness and enhance training returns. Indeed, wearable activity trackers have emerged as an increasingly popular method for users to assess their daily physical activity and energy expenditure. Commonly, these wearables measure and convert physiological data, e.g. heart rate variability, into actionable information needed by the user to monitor or change daily workout intensity in order to attain a fitness target more rapidly, push performance envelopes or reduce the likelihood of overuse injuries. With the increase in popularity, such wearable-based behavioural change interventions are becoming more prevalent.[14] In the same manner, wearables-based technologies could also be incorporated into firefighting training in order to strengthen current training systems and derive more optimal training outcomes amongst trainees.

One potential approach to implementing wearables-guided training is illustrated in Figure 4. Under this framework, each trainee wears a wearable device, e.g. smartwatch, which senses and logs his physiological responses to training and rest (including sleep) accrued from each day of training. Upon reveille the following day, all wearable devices are synced via data beacons, e.g. personal smartphones, to a cloud-based data analytics server that will determine the readiness-to-train level of every trainee. Such data will be channelled onto a trainer's dashboard software, which will categorise trainees into three groups: undertrained, optimally trained and overtrained. Trainees in each group will receive dedicated physical training programmes for the day. For instance, undertrained trainees will partake in more physically intensive workouts to maximise their training potential, while trainees belonging to the overtrained group will receive either a less physically intensive workout to reduce the likelihood of overuse injury. This cycle of events will occur on a daily basis throughout the training period. Such a progressive training strategy is expected to enhance physical fitness and performance levels in trainees, which translates into superior protection against environmental hazards and improved execution of job-specific duties.

Conclusion

Physiological status monitoring and wearables technologies have the potential to positively transform training and operations. Timely acquisition of individualised T_c and PSI data can be used to enforce thermal safety measures and therefore reduce the risk of heat illness and improve work sustainability. To this end, DSO's HSM system offers a workable solution to realise this intent. Furthermore, wearable activity trackers allow academy trainers to monitor individual-specific training load on a continuous basis. In this paper, we propose an approach to translate wearables data into periodisation of training for under- and over-trained servicemen to better adapt to training and minimise the risk of developing injury.

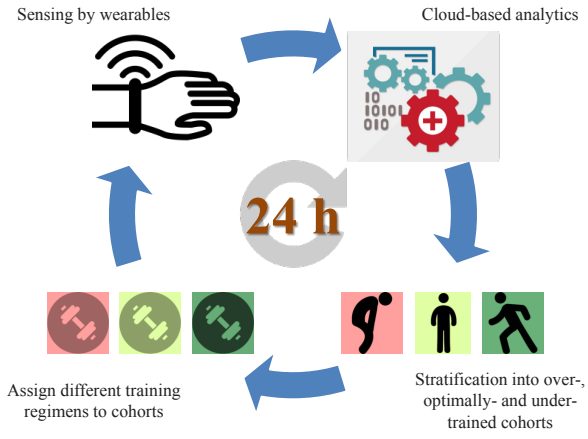

Figure 4: Wearables-guided training for optimised training returns in academy training.

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EDITORIAL PREVIEW

There have been many advances in the field of heat stress mitigation and recovery following work and exertion in Personal Protective Environment (PPE). Firefighters are expected to be fit, hydrated, and nourished to be effective. However, fatigue and heat stress are unavoidable, and it is therefore important to study the methods that are most effective in promoting recovery following work and exertion in hot environments. In 2012, SCDF began exploring the science behind fire rehabilitation with DSO National Laboratories, and the Responders' Performance Module (RPM) was thereafter developed to investigate the effectiveness of fire rehabilitation and its impact on local operational needs.

Heat stress and exertion following fire suppression affect multiple aspects of performance including gait, balance, and cognition. It can also limit physical performance, and in certain cases be life-threatening. Recent studies have highlighted these issues and provided guidance on the most effective techniques to keep firefighters healthy. This article expounds on the advances in this area, and talks about the effects of fire suppression on firefighters' health and wellness. The Editorial Board would like to thank Professor Dave Hostler for this article.

FIREGROUND REHABILITATION – KEEPING FIREFIGHTERS SAFE & EFFECTIVE

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Introduction

Firefighting and Hazardous Material (HazMat) response are physically demanding occupations. Protective garments in a hot and humid environment place additional strain on a person's body (refer to Figure 1). The combined physiological effects are referred to as Exertional Heat Strain (EHS). Severe fatigue and high body temperatures are unavoidable consequences of EHS. It is hence important for firefighters to be physically fit, and to give careful consideration to recovery following emergency response.

Physiological Response to Fire Suppression

Field studies of fire suppression have reported core body temperatures of 38°C to 40°C after 20 to 30 minutes of work from firefighters donned in protective garments and Self-Contained Breathing Apparatus (SCBA).[1][2] The body's natural response to rising heat is perspiration, which is a result in the loss of body water. An undesirable consequence of perspiration is a reduction in blood volume. This will force the heart to beat harder and faster to deliver oxygen to the working muscles, in order to keep up with the demands of the work. Although it is well known that heart rate is high during fire suppression, a recent study from our group recorded the Electrocardiogram (ECG) of firefighters during fire suppression, and discovered that more than 71% of healthy firefighters exceeded their maximum exercising heart rate during firefighting activity.[3] A bigger concern lies in the fact that a third of these firefighters had pathological ECG changes that persisted into the recovery period.

The effects of heat stress during fire suppression go beyond the cardiovascular system. The bulky protective clothing and SCBA challenges a firefighter's balance.[4] Once the firefighter becomes hot and fatigued, they experience more variable gait patterns, which may increase their risk of falling when encountering an uneven or slippery surface.[5] An act as simple as maintaining a steady support while standing is challenging when one is hot, fatigued, and wearing protective garments.[6]

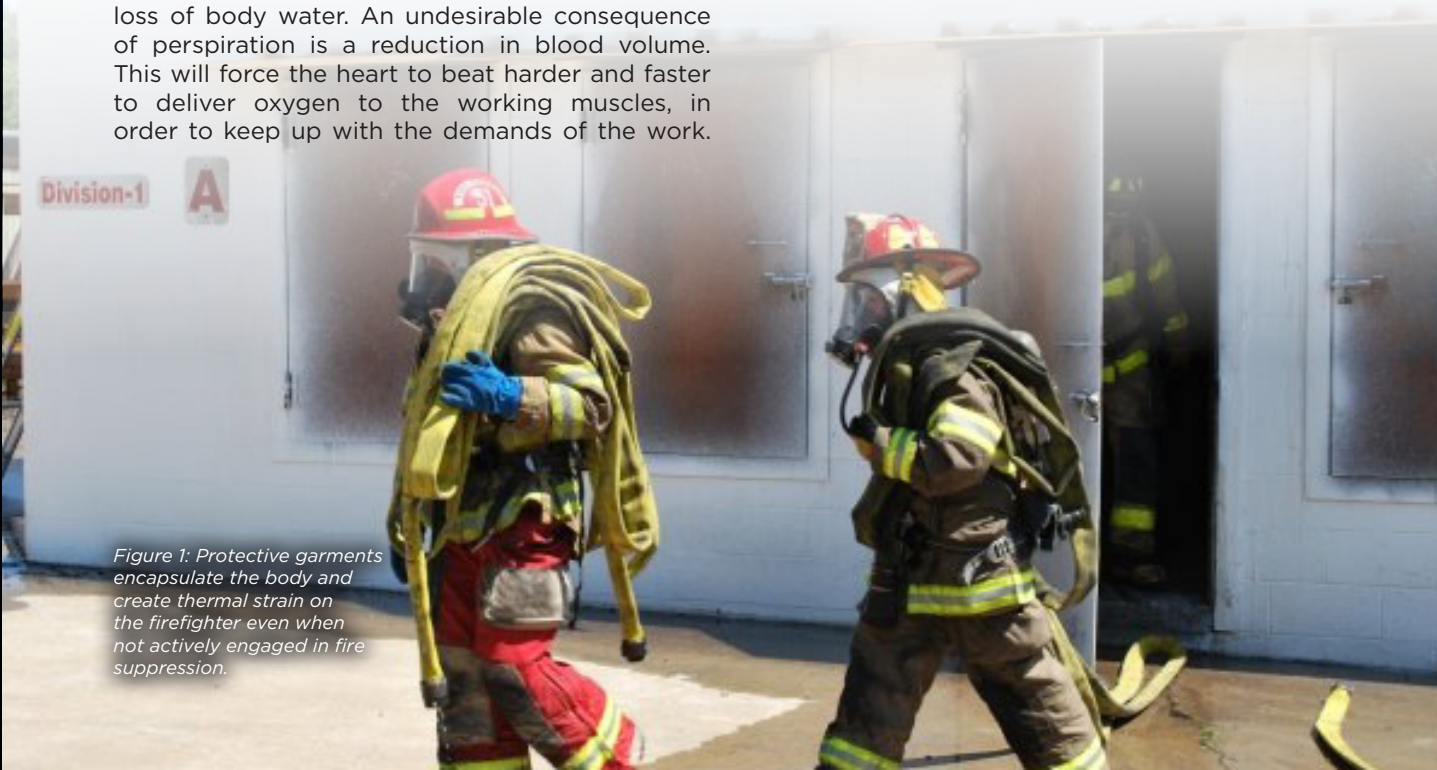

Figure 1: Protective garments encapsulate the body and create thermal strain on the firefighter even when not actively engaged in fire suppression.

Fatigue and heat stress also challenges an individual's ability to think clearly and make good decisions. Studies have shown that cognition and risk-taking behaviour are not affected immediately after heart stress in protective garments.[7] This may be related to a high state of arousal and readiness during fire suppression. However, it is revealed that in one or two hours' time, the effects of fatigue become more pronounced and subjects perform worse on tests of memory and reaction time.[8] This could make a firefighter less effective at a second emergency incident that occurs later in a same shift.

In addition to these impairments, recent studies have reported that heat stress is worse on the second day when fire suppression is performed consecutively. Prolonged heat stress may also result in acute kidney injury.[9][10] These new findings should drive the consideration in managing shift schedules in order to take care of the long-term health and welfare of firefighters.

Role of Fitness

While high fitness levels cannot prevent the ill effects of EHS, it can reduce the magnitude. High cardiovascular fitness allows the firefighter to work at a lower heart rate at nearly every level of exertion, reducing the total fatigue and conserving energy. Fit firefighters who are hydrated and heat acclimatized consume lesser body water during exertion, leaving more fluid to support blood delivery to working muscles. However, aerobic fitness alone cannot alter all the issues highlighted in the previous section.[11] Firefighters must have sufficient strength to advance hose, move ladders, and carry and drag heavy loads. Since fire suppression is a demanding activity performed at relatively high intensity, firefighters should consider developing strength and muscular power in conjunction with a metabolic conditioning program. This type of training program may allow the firefighter to continue executing movements requiring strength, even when the heart is under high strain. However, research remains significant to identify the best training paradigm for firefighters.

Hydration

Being hydrated is an important component of managing EHS. While healthy individuals can tolerate mild dehydration (<2% of body mass), sweat loss resulting in severe dehydration will result in higher heat and cardiovascular strain during fire suppression. It is shown that firefighters typically lose 700ml to 1000 ml of body water from perspiration during fire suppression.[1][2] Additional bouts of work result in even greater dehydration.[9] While it is important to replenish some of the fluid loss in this instance, it is equally important for the firefighter to understand that full rehydration may take multiple hours.

The choice of rehydration solution is less crucial. When a firefighter is fully rehydrated, neither the sports beverage nor water differs in terms of performance during a second bout of heat stress.[1] There may be some advantages to sports beverages during longer incidents. The simple sugars in these beverages may sustain the firefighter when their internal energy stores have been consumed. However, sports beverages add calories to the diet, and should not be used routinely throughout the day.

It is important to ensure that a rehydration beverage is always available during an incident. It is a simple task to put bottled water in every emergency apparatus to make sure that all firefighters have immediate access to such remuneration. Waiting for a designated vehicle to arrive with fluids allows for more fluid loss before rehydration can begin. One commonly-used method to make water available is to place bottles of water with spare SCBA cylinders (refer to Figure 2). This provides a visual cue and immediate access when the firefighter changes his SCBA cylinder for the next bout of work.

Figure 2: Storing bottled water with spare SCBA cylinders provides immediate access and a visual reminder for the firefighter to rehydrate during an incident.

While dehydration is a critical problem for firefighters, over-hydration should also be avoided. Drinking too much water during heavy exertion can dilute the body's compartments resulting in hyponatremia.[12] More commonly seen in recreational runners, hyponatremia can result in severe symptoms and death. One method to avoid severe dehydration after an incident and to sustain long-term health is to weigh one's self every morning. Once a normal body mass has been established, one can use the normal body mass as a reference to determine the degree of dehydration after an incident, and the amount of fluid to be consumed in the next few hours. Another option is use urine colour charts to remind firefighters that urine should be pale but not clear (refer to Figure 3).

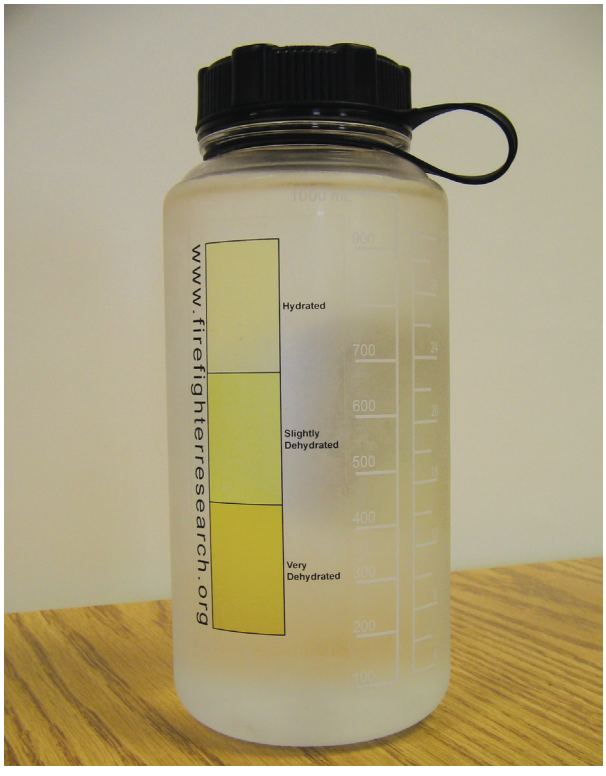

Figure 3: Simple urine colour charts remind firefighters that urine should be pale in colour but not clear.

Cooling

Rising body temperature is an unavoidable aspect of firefighting and HazMat response. The gear that is essential to protecting you from the environment prevents sweat from evaporating which causes your body temperature to rise dramatically in the heat. Without sufficient opportunity to rest, this rise in body temperature can result in serious illness or death.

Mitigating heat stress is relatively straightforward if you carefully consider the environmental conditions and remove protective gear. Removing protective garments is the most important aspect of cooling. Sweating is the most important mechanism available to the body for cooling but sweat will not evaporate while the firefighter is covered in garments. At the minimal, the helmet, hood, gloves, and coat must be removed. If the firefighter is wearing a long-sleeved shirt, the sleeves should be rolled up to expose the skin on the arms. Pushing the protective trousers down below the knees will further enhance cooling during the rest interval.

Our studies have shown that the body can effectively reduce temperature without any cooling devices if the firefighter is sitting in a cool and dry environment. [13, 14]This optimal environment could be created in an air-conditioned vehicle or a nearby building. However, passive cooling will not be effective if the firefighter must recover in a hot or humid environment. In this scenario, an active cooling strategy must be implemented. While many cooling devices are available, one of the most effective and easiest to deploy is forearm immersion. The firefighter removes the protective garments and immerses the hands and forearms into containers of cool or cold water (refer to Figure 4). The conduction between the skin and the water allows cooler blood to return to the torso, which facilitates cooling in the rest of the body.

Figure 4: Forearm immersion into containers of cool water is an effective method of active cooling after EHS.

Other available cooling strategies include fans and wet towels. Fans can create convective currents over exposed skin, which can increase cooling rates. If fans are deployed during the rest interval, they must be placed close enough to the firefighter to create significant airflow over the sweating skin. Using a fan to cool an area, as opposed to placing it in front of an individual, will be less effective. It may not be necessary to use a misting fan. Firefighters are already perspiring; placing additional moisture on the skin with a misting fan is unlikely to speed evaporation. Cold and wet towels are often draped over the head and neck to promote cooling. While this feels good, the conductive capacity of a wet towel is low, and it is not generally considered to be an effective cooling modality.

Conclusion

The ill effects of EHS are unavoidable during fire suppression and HazMat response. While the firefighter must prepare in advance by maintaining fitness and good hydration, it is the responsibility of the fire service officers to provide adequate rest and recovery during and after the incident to ensure that firefighters do not suffer from severe heat injury.

Hydration and cooling strategies can be scaled to match the size of the incident (refer to Figure 5). Small incidents (Awareness Level) require few resources. Equipping every vehicle with the minimum equipment to rehydrate and cool firefighters ensures that firefighters are well-prepared for the next incident after every emergency response. Larger and prolonged incidents (Operations Level) will require a dedicated group of individuals to create a recovery sector with sufficient cooling resources, and an ample supply of food and beverages. The largest incidents (Technician Level) will challenge even the most well-developed system, and will require multiple sectors and a detailed plan to provide adequate rest, cooling, hydration, and nutrition for a large number of responders.

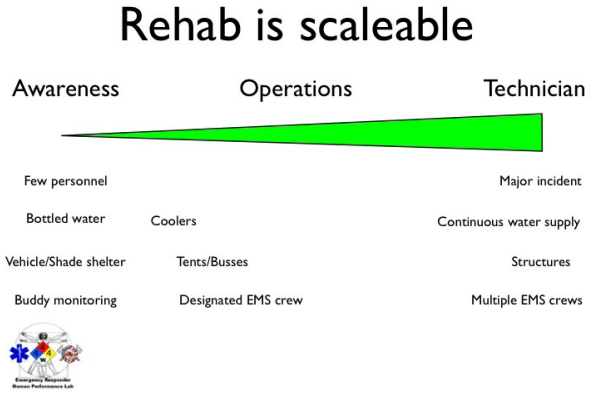

Figure 5: Resources for recovery can be scaled to match the size of the incident.

In conclusion, recovery during and after an emergency incident must be planned. Officers and firefighters should recognize the importance of recovery, and provide resources and operating guidelines to ensure firefighters and HazMat technicians remain safe and effective.

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EDITORIAL PREVIEW

Mitigating large scale fires has never been an easy feat. It is highly labour-intensive, and requires the involvement of many resources. In the Pulau Busing oil storage tank fire in March 2018, a total of 128 personnel and 31 appliances were deployed to respond. In light of the manpower limitations in the coming years, SCDF took a step into exploring the use of Exoskeleton technology to maximise the capabilities of a firefighter. Inspired by the existing power-multiplying Exoskeletons out in the market, SCDF hopes to reinvent this technology in the field of firefighting.

In this article, SCDF shares its progress on the development of an Exoskeleton suit appropriate for use in firefighting conditions. The Exoskeleton suit strives to enhance a firefighter's ability to carry heavy loads, as well as reduce the fatigue experienced during firefighting operations.

This article also provides an overview of the trials conducted which quantitatively demonstrated the increase in an individual's performance with the use of the Exoskeleton suit. Read on to discover more about how the Exoskeleton suit was envisaged for the future of firefighting.

EXOSKELETON – OPERATING ABOVE & BEYOND

CPT Jonathan Yuen Ze Ming, Senior Staff Officer, Operations Department
Singapore Civil Defence Force

Introduction

The impetus of this ambitious development of the Exoskeleton is to reduce the load off our responders, both figuratively and literally. A powered Exoskeleton is a wearable mobile machine that is driven by a system of electric, pneumatic, or hydraulic actuators and levers, or even a combination of technologies that allow for limb movement with increased strength and endurance.

An Exoskeleton system strives to enable the SCDF frontliners to carry heavier loads or improve their physical endurance in demanding operating conditions. Commercially, the Exoskeleton technology has been in the market for many years, and is mainly applied to the manufacturing and healthcare industries. However, when it comes to the context of emergency response, Singapore could potentially be the first to employ the Exoskeleton technology.

SCDF, together with the Ministry of Home Affairs, Office of the Chief Science and Technology (MHA, OSCTO), jointly embarked on the development of Exoskeleton capabilities to explore the application of this technology with the purpose of enhancing its responders' performance in firefighting, rescue, and medical response. Taking on the principal considerations of developing an Exoskeleton fit for firefighting would allow responders to focus on the tasks at hand, and make better decisions on the ground, as the suit aims to alleviate the effects of muscle fatigue.

Prototype Development

The development of the Exoskeleton is a challenging task, as a delicate balance between the competing operational requirements, safety considerations, and technology constraints must be carefully thought through. The Exoskeleton system needs to be able to withstand the extreme operating environments SCDF frontliners are subjected to – enhancing performance without compromising on personal safety.

For the Exoskeleton system to be suitable for use in a fire, the materials used in the construction of the suit have to be able to withstand the heat from the fire. In the event that the user is trapped, and the integrity of the Exoskeleton system fails, there must be safety measures in place for the user to eject swiftly and navigate out to a safe zone. Therefore, the development of the Exoskeleton suit has to be meticulously considered to ensure that frontliners are able to complete their assignment efficiently and safely at the incident site, minimising and eliminating any mishap that may arise. With these principles in place, three parallel developments with different actuation systems were explored and tested.

Prototype 1 – Hydraulic System

In Prototype 1, a full-height humanoid Exoskeleton powered with a battery-operated hydraulic system was piloted. The Hydraulic Power Unit (HPU) is mounted centrally on the back of the upper frame, with two directional control valve manifold blocks on each side of the HPU. Each of the blocks is equipped with five double acting valves that provide hands and legs actuation. Tests revealed that this Exoskeleton system was too heavy for deployment, and operators faced difficulties with balancing the load of the Exoskeleton suit, due to the inefficient transfer of weight between the legs when walking.

Prototype 2 – Electrical System

In Prototype 2, a non-anthropomorphic approach was adopted with the implementation of point-to-point kinematics without human joint positions. In this configuration of an electric motor actuator with a non-knee joint concept, the Exoskeleton suit design does not take into account the actual joint locations, thus negating the need to design a complex limb cuffing with adjustable limb lengths to match the actual position of the joints. This concept translated to minimal mechanical parts needed to make the Exoskeleton interconnected. Similar to Prototype 1, Prototype 2 is also powered by a battery pack, lasting between 45 to 60 minutes. However, the transitional speed for limb extension and retraction was not responsive; hence, this version of the Exoskeleton suit faced a similar challenge in providing balance, and was not suitable for demanding operational situations.

Prototype 3 – Pneumatic System

Prototype 3 uses pneumatics as its primary power delivery system. This Exoskeleton suit is driven by compressed air through two standard Breathing Apparatus (BA) cylinders. Providing tether-less operations, the pneumatic system generates lesser heat as compared to the electric and hydraulic set-ups (refer to Figure 1). Not only does the design reduce the weight of the Exoskeleton suit, it also eliminates the need for any electrical components, which are susceptible to malfunction during operations. The pneumatic system was eventually chosen as it offers the reliability of having no risk of electrical failure, provides superior safety due to the lightweight construction, and allows for the use of existing SCDF BA cylinders, avoiding the costs of developing a dedicated power source.

Figure 1: A pneumatic powered exoskeleton system

Prototype 4 – Enhanced Pneumatic System

In November 2017, two sets of pneumatic-powered Exoskeleton suits were developed for Proof-Of-Concept (POC) trials. The design of the Exoskeleton considered strong human factors engineering methodologies to create a highly dextrous system with multiple degrees-of-freedom for close conformance to the user's anthropometry (refer to Figure 2).

Figure 2: The exoskeleton being trialled at the human performance centre

The design targets to reduce the muscular stress placed on the user's shoulders and back, by transferring the weight of the equipment through the Exoskeleton down to the ground via the footplates. The functionalities and safety of the Exoskeleton prototype were robustly tested and verified at an in-house Human Factors assessment facility.

Several key improvements from the biomechanics profiling were observed:

1. Reduction of pressure points on shoulder and spine
2. Improved design of footplate relieves pressure points
3. Adjustable knee pads suits various user heights and walking styles

One new upgrade includes the change of lighter materials used to construct the Exoskeleton frame. The use of carbon fibre and aluminium took significant weight off the entire system. The Exoskeleton suit design also features a pair of innovatively-designed mechanical knee sensors (refer to Figure 3) that predicts the movement of the user's lower limbs to provide the necessary actuations for enhanced load-bearing. The Exoskeleton prototype functions on the concept of providing load-bearing support to the user's knees. It augments the user's ability to sustain heavy loads carried during operations, such as fire-fighting, medical evacuation, and urban search and rescue missions. The pair of compressed air actuators gives the user's knee muscles and joints the mechanical advantage during walking and stair-climbing gaits. Augmented by the Exoskeleton, SCDF frontliners could potentially carry heavy loads with lesser stress on their physical endurance in demanding operational conditions

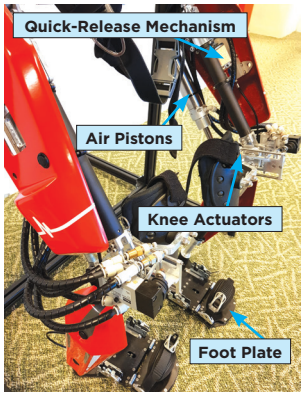

Figure 3: Lower limb design

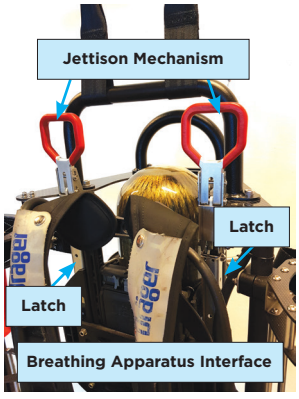

Figure 4: Jettison System

Besides the mentioned features, Prototype 4 also includes a jettison mechanism (refer to Figure 4) that allows the operator to eject the system swiftly in times of malfunction or emergency. These levers are easily within the user's reach and will only release the Exoskeleton frame, leaving the BA set attached to the user.

Controlled Outdoor Trials

In September 2017, Prototype 4 was put through a series of trials with outdoor technical trials conducted in the Civil Defence Academy (CDA). The inaugural trials tested its capabilities on walking and climbing endurances as well as pivot lifting of a 130-kilogram concrete slab. Initial findings are shown in the table below:

In September 2017, Prototype 4 was put through a series of outdoor trials conducted in the Civil Defence Academy (CDA). The inaugural trials tested its capabilities on walking and climbing as well as pivot-lifting of a 130-kilogram concrete slab.

The participants underwent the trial procedures in four different configurations:

1. SCDF's field attire with a BA set;
2. SCDF's field attire with a BA set and a 20-kilogram external load;
3. Donning the Exoskeleton suit with a BA set and;
4. Donning the Exoskeleton suit with a BA set and a 20-kilogram external load.

Through the trials, it was observed that Prototype 4 demonstrated its reliability with no major failures reported. The safety of the system was also demonstrated sufficiently with no major breaches in the walking and climbing trials. As for the effectiveness in improving endurance, it was observed that strain was taken off the user's shoulders as the Exoskeleton effectively transferred the load from the human to the ground. Several areas of improvements were also identified from this trial. Notably, there could be further reduction in the physiological loading of the users. The need to ensure proficiency of the users in operating such a system is also paramount.

Station Trials

In July 2018, SCDF tested the functionality of the Exoskeleton suit among SCDF frontliners in the fire station. The 12-month trial involved six firefighters from Paya Lebar Fire Station whom underwent an intensive training regime to understand the operations behind the Exoskeleton suit. A series of scenarios were introduced to determine the frontliners' comfort in donning and using the Exoskeleton suit. Through the rigorous process of training and testing, feedback was solicited from the trial subjects in order for fine-tuning of the system to be considered.

Conclusion

As much as the trials are still in progress, the application of the Exoskeleton technology does indeed hold much promise in providing additional strength and endurance to our frontliners. In the near future, committing lesser resources for prolonged incidents could therefore be unexpectedly possible. This reinvention would go a long way to assist SCDF in the upcoming manpower crunch.

EDITORIAL PREVIEW

It is always a massive benefit when technological advancements are used for the common good, such as to aid in emergency response. While the use of drones have been talked about in science fiction films for years, it is only recently that we are beginning to see their full potential in the real world. The innovations in the world of drones have led to surveillance operations equipment that are smaller, more agile, better controlled, and better equipped for use by emergency services. Drone selection becomes important as it dictates the level of performance desired for a particular emergency. SCDF has incorporated the use of drones into its operational resources for the purpose of aerial reconnaissance. Despite its infancy, this operational capability provides much potential to the field of emergency response – especially in the face of situations which are dangerous or difficult to assess in person.

In this article, the author explores the strengths and weaknesses of fixed-wing drones and multi-rotor drones, discussing different scenarios where one drone design might be favoured over another. Find out more about drone selection in this article written by SkyBound Innovations. The Editorial Board would like to thank Ms. Gemma Alcock for sharing on this subject in this publication.

SELECTING A DRONE FOR EMERGENCY RESPONSE

Ms. Gemma Alcock, Founder & Managing Director of SkyBound Innovations
United Kingdom

Introduction

An emergency service should avoid simply following the status quo of multi-rotors and really assess their drone-use cases before selecting their airframe. Ultimately, the choice of drone will dictate a drone team's capabilities and the level of performance that can be achieved.

The drone model that an emergency service decides to purchase dictates what drone capabilities they have and the level of performance they can achieve, thus making drone selection an integral variable in establishing best practices.

The EENA / DJI Pilot Project Report highlighted the following as the minimum drone configuration for First Responders:

- Reliable platform with redundant systems, i.e. minimising single points of failure within the system
- Global Navigation Satellite Systems (e.g. GPS)
- Integrated camera systems, preferably modular, with live downstream capabilities in HD format
- Ability to fly in moderate winds and light rain
- Integrated SDK (Software Development Kit) so that specific apps can be written to help operators, for example, the DJI/DroneSAR Search and Rescue app, DroneDeploy for 2D and 3D mapping, and many more

Several organisations are claiming to offer 'search-and-rescue drone options', yet seem to be simply offering a thermal camera to be coupled with their consumer or commercial drone, without any or very little adaptation to the airframe. A ruggedised Search-And-Rescue (SAR) worthy payload has limited value if the airframe hasn't been designed to the same standard.

An SAR drone needs to be more than just a consumer/commercial drone with a thermal camera attached to it; its SAR capabilities need to extend further than its payload. For this reason, this 'Selecting a Drone for Emergency Response' series of articles will analyse each main component of a drone system individually, starting with airframe selection.

A fixed-wing drone (senseFly eBee) being hand-launched.

Strengths and Limitations of Drone Types

Although the majority of emergency services seem to have converged on small multi-rotor drones as the default platform, other models should not be dismissed. The following sections will summarise and then discuss the two main categories of drones: fixed-wing (which look and act like a plane or jet) and multi-rotors (which act similar to a helicopter).

The main strengths of a fixed-wing drone:

- They generally fly at higher speeds than multi-rotors
- They are usually able to fly at higher altitudes
- They are a lot more energy efficient than a multi-rotor and thus will have a much longer flight duration (range)

The main weaknesses of a fixed-wing drone:

- Most are limited by the need to take-off and land laterally, so terrain will affect launch and recovery sites
- They cannot be used in restricted or congested areas because of their requirements to move through the air to generate lift
- Without a stabilised camera, video imagery from a fixed-wing drone can be difficult to interpret due to the constant airframe motion
- Fixed-wing drones are influenced by aerodynamics much more so than multi-rotors, thus attaching a payload that hasn't been specifically designed for the drone can considerably disrupt its flight performance by changing its aerodynamic shape.

The main strengths of a multi-rotor drone:

- Multi-rotors, with three, four, six, eight, or more powered rotors, benefit from mechanical simplicity and redundancy in higher-number configurations
- They have the ability to launch from, manoeuvre in, and recover to very restricted terrain
- They can provide a steady video picture from a stationary, top-down perspective
- Aerodynamics influence a multi-rotor drone much less so than a fixed-wing model, thus retrofitting payloads to the drone can be achieved seamlessly, providing the aircraft's centre of gravity and maximum take-off weight have been considered first.

The main weaknesses of a multi-rotor drone:

- Hovering requires more power than fixed-wing flight, so multi-rotor platforms will have shorter flight times, lower top speed and lower altitude limits than equivalently sized fixed-wing airframes.

Discussion

Austin Fire Department's Robotic Emergency Deployment (RED) Team and Wimberley Fire Department's Unmanned Aircraft Team collaborated on a report, 'Using Unmanned Aerial Systems During a Natural Disaster in Texas', to reflect their lessons learnt from implementing drones at the 2015 Texas Memorial Day Floods, recently dubbed as a "millennial flood" due to its severity. Interestingly, a key recommendation that the report offered was: "Provide Incident Command with both fixed-wing and multi-rotor capabilities." Both a fixed-wing and a multi-rotor drone were used to great effect throughout the Texas flooding event. The two report extracts quoted below indicate the rationale behind the selection of each drone based on the application it was to fulfil, along with the drawbacks to each selection.

"The Wimberley aviation unit found fixed-wing unmanned aircraft launching, recovery, and visual observation somewhat difficult due to high tree lines, rocky river bottoms, steep cliffs, vegetative undergrowth, and at times, a densely residential population. However, the range flown and time involved dictated this choice. The Spectra has long flight endurance and using its autopilot provides precise imagery over large areas (1.77" or 4.5cm resolution at + or – 10cm accuracy)."[1]

"Multi-rotor aircraft was favoured at times over the fixed-wing for its vertical take-off and landing capability. Early in the flood response, a DJI Inspire quadcopter was used to collect imagery for the primary search. The ability to get on scene, take high-resolution imagery, and then move to the next location in minimal time made the Inspire a great tool for low altitude information gathering (100'-200' above ground level). Multi-rotor platforms can provide a quick frame of reference and influence decision-making that might normally place responders in areas of danger."[1]

With these comments in mind, both types of airframe clearly offer great advantages to Emergency Service personnel, whilst also having separate performance limitations to consider. Hence, hybrid drones are rapidly emerging to combine the strengths of both fixed-wing and multi-rotor drones, thus reducing the inherent weaknesses of each. Hybrids usually have a vertical take-off and landing (VTOL) and then transition into fixed-wing flight after launching, combining a multi-rotor's ease of launch and landing with a fixed-wing's longer flight duration. It should be noted that, at present, hybrid drones are at a lower level of technology maturation and market penetration than solely fixed-wing or multi-rotor type airframes, and thus currently come at a greater cost when comparable in quality. That said, based on the pattern of most technologies, we can assume as hybrid airframes mature and grow in popularity, the cost will likely decrease over time.

Similarly, another approach that could merge the benefits of both drone categories is through the concept of "swarm" technology. Put simply, swarm technology gives a drone the ability to work in conjunction with multiple other drones in the same space by constantly knowing the location of all drones in the surrounding area, thus allowing the drones to avoid each other autonomously. To contextualise, swarm technology allowed Intel's drone display team to fly over 1,200 drones above PyeongChang for the Opening Ceremony of the Winter Olympic Games; the illuminated drones worked together to cleverly form shapes, such as a snowboarder and the Olympic rings, across the night sky. Into the future, as swarm technology matures, it may be possible to simultaneously reap the benefits of operating both fixed-wing and multi-rotor drone models; an Emergency Service would have the ability to deploy both kinds into the same search area for different roles. A fixed-wing drone could be used to cover large search areas quickly, with the multi-rotors examining all significant finds detected by the fixed-wing drone. This technology is unfortunately not matured enough to be feasible at present, but the concept of swarm technology is receiving great interest from the research community, as well as the tech giant, Intel – which is currently pioneering this area of drone technology, so perhaps it could emerge as a viable option for the First Response sector in the not-so-distant future.

Conclusion

As the technology evolves, the weaknesses of both choices will reduce, and is already occurring – for example, the duration of a multi-rotor is constantly rising as battery technology improves – but their operational style will remain the same: fixed-wing drones are far better for wide-area operational environments, whereas multi-rotors are best for local-area operational environments. Realistically, an emergency service could need both. However, given emergency services' clear preference towards small multi-rotor drones, one can assume the ability to hover and ease of launch/recovery must outweigh the requirement of long endurance. Having said that, generally speaking multi-rotors can be lower in cost than fixed-wings of comparable quality, which is likely to be a key deciding factor for an emergency service.

Additionally, the current legal parameter in the United Kingdom of 500m as a maximum flight distance, prevents drone operators from utilising the full benefits of a fixed-wing's range – although there are exemptions in place for emergency services if there is immediate risk to life (see General Exemption E 4506). All of these factors – and more – have lead multi-rotors to be the popular 'go-to' choice. Nonetheless, an emergency service should avoid simply following the status quo of multi-rotors and should really assess their drone use cases before selecting their airframe; perhaps their local operational area may suit a fixed-wing drone instead.

For more information, go to www.skyboundrescuerproject.com or email skyboundrescuer@gmail.com

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[1] Kessler, C., Robinson, G., 2015. Using Unmanned Aerial Systems During a Natural Disaster in Texas. Texas: Austin Fire Department – Robotic Emergency Deployment (RED) Team & Wimberley Fire Department – Unmanned Aircraft Operations.

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EDITORIAL PREVIEW

The fire service is an ever-changing machine that keeps evolving to meet the needs of the citizen it is designed to protect. With the manifestation of technology today, the advances in firefighting apparatus have been remarkable. To cater to local needs, SCDF conceptualised the Fire Medical Vehicle (FMV) and the Fire & Rescue Operations Support Tender (FROST) by integrating core requirements into one vehicle. Likewise, the Lancashire Fire & Rescue Service, in collaboration with the Greater Manchester Fire & Rescue Service, developed its very own AT-Stinger by integrating several support functions commonly used in the United Kingdom (UK).

Find out more about the capabilities of this invention in this article as the author discusses the thoughts behind this creation. The Editorial Board would like to thank Mr. Justin Johnston for this article.

THE UK FIRE APPLIANCE CHANGING THE FACE OF FIREFIGHTING

Mr. Justin Johnston, Deputy Chief Fire Officer of Lancashire Fire and Rescue Service
United Kingdom

Introduction

Over the past few months, one fire and rescue service in the UK has been putting a brand new fire appliance to the test. This single truck – which is the only one of its kind in the country – along with the people who've been operating it, are helping to shape future frontline firefighting across the world...

Current funding pressures mean that fire services up and down the United Kingdom need to operate more productively than ever before.

It's a common scenario: fire crews are called upon to improve the speed, efficiency and power needed to react to an emergency incident. But budgets are simultaneously being tightened, meaning that services are effectively being asked to do more, with less.

The best approach to tackling this feat is via a combination of continual improvements in planning and training, alongside the innovation of new, ground-breaking technology.

And Lancashire Fire and Rescue Service (LFRS) is a great example of a service that achieves this.

A collaborative effort

In 2012, in an attempt to accomplish said efficiency, LFRS recognised the growing need for a new, multi-purpose appliance. John Hargreaves, their head of fleet and engineering services (FES), was tasked with researching options, working in collaboration with Greater Manchester Fire and Rescue Service (GMFRS) to produce a framework for special appliances – including aerial ladder platforms (ALP), turn table ladder (TTL) and water tower (WT) vehicles.

The subsequent reports created by John recommended the development of an aerial strategy and the introduction of a water tower appliance. This vehicle needed to be capable of self-sufficiency, whilst simultaneously increasing firefighter safety.

And so, after months of state-of-the-art research, development and simulation methods – in collaboration with Rosenbauer UK, the AT-Stinger appliance was born.

The specification

A Bluetooth-controlled, 16.5 metre High Reach Extendable Turret (HRET) is able to deliver 4,500 litres of water over 85 metres, if and when required – further than any ALP. It allows fast, precise positioning and extinguishing performance.

The Stinger boom package was also designed with a hydraulically-actuated piercing tool, capable of penetrating walls, windows and house roofs, before discharging 1,000 litres per minute of water from the injected spike. A thermal imaging and real-time camera are fixed to the tip of the implement, alongside LED lighting to illuminate the scene of operation.

The water supply performance is powered by its own - 4,500-litres-per-minute - Rosenbauer NH45 fire pump, which was developed specifically for the AT-Stinger.

Firefighter safety was also at the centre of innovation. Three-point belts were fitted on all seats, alongside an optional complete roll-over airbag system in the crew cab. Patented revolving safety steps allow the firefighters to enter and exit the vehicle quickly and safely, even whilst wearing bulky PPE and breathing apparatus and when the door can only be opened halfway. Plus, LED lighting ensures glare-free, uniform lighting with the option for night vision mode to ensure maximum efficiency.

The AT Stinger boosts human safety, often allowing firefighters to stay away from some of the dangers of falling structures.

State-of-the-art construction

Part of the AT-Stinger's specification was a robust and corrosion-resistant unit to offer further precision. Laser-cut, bent aluminium offers a high-strength body which is self-supporting and torsion-resistant.

All these refinements make the resulting AT-Stinger a light unit, to ensure ease of operational handling.

But, perhaps most significantly of all, the appliance also has the ability to carry the most essential component for dealing with any fire or rescue scenario; up to six highly-skilled firefighters.

Putting the concept to the test

So the appliance was built and tested, and 2017 was the year to put the AT-Stinger and its cutting-edge functions into operation.

During a 12-month hire agreement, the AT-Stinger was stationed at a Lancashire fire station and put through 460 demanding emergencies.

A hint of the triumph to come was seen at the AT-Stinger's first operational incident; a house fire in Blackburn. It took the appliance just six minutes to set up and extinguish the fire from arrival, whilst providing additional safety and breathing apparatus for the crews committed inside the building.

Another instance of the AT-Stinger's superior performance was seen at a car recycling plant in Hyndburn. Where other trucks would struggle to gain access due to rough ground conditions, the water tower successfully navigated the terrain and set to work from a safe distance, increasing firefighter safety.

Without the AT-Stinger in attendance, most industrial and recycling factory incidents would have ordinarily required dedicated aerials and countless pumping appliances to feed them.

In fact, throughout 2017, the benefits of this revolutionary truck were seen time and time again. For instance, the long jet throw capability often kept firefighters in a 'safe zone', away from some of the dangers of falling structures and hazardous chemicals.

The speed and efficiency of the vehicle also reduced attendance time and the need for multiple units on the scene, increasing appliance availability for more life-threatening scenarios.

And, together with its capability of dealing with large-scale fire, the AT-Stinger also showed itself as a workhorse for 'everyday' incidents, where required. Carrying 1,500 litres of water and a varied allocation of firefighting equipment – including the new battery-operator Weber E-Force 2 extrication equipment – the machine provided increased cutting and spreading power at Road Traffic Collision incidents.

Environmental benefits were also proven, so much so, that the Environment Agency expressed an interest in the AT-Stinger being recognised as a national and regional asset.

Lancashire's official report attesting to the robustness of the AT-Stinger – released in late 2017 – demonstrates this fire fighting appliance as the most versatile, aggressive and clinical in the UK. This evaluation paves the way for other fire services to invest in this cutting-edge technology.

Skilled personnel alongside cutting-edge innovation

The concept of the AT-Stinger has now been proven, but the success isn't just down to the technology. It's also attributed to Lancashire Fire Service and their highly skilled and enthusiastic crew, without whom the appliance wouldn't have served at its fullest potential.

Oliver North of Rosenbauer UK said: "I have never seen an appliance quite as effective as the AT-Stinger. Many similar concepts, or combined aerial concepts, have been trialled in the past but have never been executed effectively.

"The crews that utilised the AT-Stinger during its trial at Blackburn fire station have been as impressive as the machine itself, and have used it as a tool in their armoury. Lancashire Fire and Rescue Service have truly embraced the technology with great effect.

"I genuinely believe this appliance serves as proof that such complex firefighting solutions are best engineered by pedigree manufacturers using their own components and technology, in conjunction with people on the front line."

Lancashire Fire and Rescue Service have now procured the rented AT-Stinger and will put a second unit into service, once built, in the autumn of 2018. This will be facilitated by the service's robust training plan, delivered by instructors at Blackburn fire station.

Justin Johnston, Deputy Chief Fire Officer of LFRS finished: "This has been a great partnership approach between Lancashire Fire and Rescue Service and Rosenbauer UK, marking investment in a time of austerity.

"Importantly, the focus has been all about increasing operational capability whilst improving firefighter and public safety. I am delighted with what we have achieved and it demonstrates the value of direct frontline engagement from design through to operational testing and, ultimately, adoption."

The AT-Stinger has therefore fulfilled its brief – speed, reliability and water power have all been proven. But above anything else, it is also a tool to improve human safety – the most important thing of all.

The appliance is now available to other Fire and Rescue Services across the globe.

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EDITORIAL PREVIEW

What would you think would be the greatest invention in firefighting? Of the many tools that were developed over the years, the top of the list had to be the Self-Contained Breathing Apparatus (SCBA). When it comes to having improved our battles with fire, the SCBA has changed how we operate. No longer are we asked to go in and see how far we can get in, as was the case many years ago.

Today, faced with ever increasing expectations from the public to improve service standards, it is essential for the fire service to enhance safety and improve efficiency in its response. This article explores the technologies needed to support emergency responders in the future. These include improvements to Thermal Imaging Cameras (TIC) and communication systems on the fire ground. The Editorial Board would like to thank Mr. Damien Eggleston for contributing to this publication with this article.

TECHNOLOGY IN FIREFIGHTING – WHAT IS COMING?

Mr. Damian Eggleston, ASEAN Marketing Manager & Safety
Dräger Singapore

Introduction

The fire service need tough equipment and in some cases, the equipment that a fire service agency want and what they eventually get can be two very different things. Technology companies spend millions of dollars in research and development to conceptualise equipment that will complement the fire service's mission to protect life and property. There is a number of factors that need to be taken into consideration when designing and testing firefighting equipment.

Firefighting is one of the few industries where engineered equipment is designed to take a human into a more dangerous place. Most engineering is designed to make the user safer or replace the need to enter a dangerous space that could injure or kill the person. Modern firefighting Personal Protective Equipment (PPE) can take a firefighter further into an affected room, or take a firefighter donned in a Chemical Protection Suit (CPS) closer to chemical contamination than ever before. PPE engineering for firefighting is becoming increasingly more challenging with advancements in customer requirements, and international standards for firefighting equipment.

Items such as the CPS, firefighting turnout leggings and jackets, gloves, helmets, flashover hoods, Self-Contained Breathing Apparatus (SCBA), and Thermal Imagining Cameras (TIC) are just some equipment that need to be approved under international standards. The most renowned agency endorsing the approval for firefighting equipment is the National Fire Protection Association (NFPA) for USA and Canada, and European Standards (EN) for European countries. EN is also used in the Middle East, Africa, and most of Asia. There are also standards for Russia (GOST), Brazil (ABNT), Australia, and New Zealand (ASNZ), India (BIS), Japan (JIS), and China (CCCF). All of these standards place different requirements on the manufacturer with different methods of testing and unique testing parameters.

Interestingly, few of these standards are complementary with one another. For example, an SCBA designed for the USA and Canada market holding the NFPA 1981-2018 Edition Standard[1] approval does not complement, or passed the test for the European standard EN 137 Type 2 Respiratory Protective Devices.[2] Likewise, the EN SCBA would not pass the NFPA requirements either.

Understanding these differences when reviewing, tendering, or ordering new equipment is important. For example, the NFPA sets uses PSI to measure air pressure while the EN uses Bar. NFPA SCBA sets and EN SCBA sets have air cylinders that are not interchangeable as they have different cylinder connections on the pressure reducer. Air compressors would require extensive upgrades to ensure that the cylinders are filled correctly. Connections for CPS would be different, and the list goes on.

The fire service have always taken an interest in innovation as there are many incredible state-of-the-art products already on the market. You may be surprised to know that internationally, the majority of SCBA sets, that are sold to fire service agencies at present, are considered "low-tech" or "basic models". They consist of a mechanical low air warning whistle and gauge, face mask, lung demand valve, back-plate, and air cylinder. All international SCBA manufacturers have telemetry options and sophisticated electronic system, such as electronic low air warning and telemetry. These have been designed and tested according to the international standards we have listed and verified against industry demand. Yet, they continue to be sold in small quantities.

What Should Be Expected in the Future

An innovation review has been carried out by the USA Department of Homeland Security in partnership with US-based technical universities and several large fire departments, such as the Fire Department of New York (FDNY). From this review, a short video has been created to present the advancement that should be expected in the coming years. Studies have been conducted not only for firefighters but for Emergency Medical Technicians (EMT) and Law Enforcement Officers as well. This study generated a number of innovative concepts, which could be likened to a wish list of technology to assist firefighters to perform at their jobs. This information can be found on the website of the USA Department of Homeland Security website.[3]

Amongst these options are uniforms with in-built telemetry that would tell the end use if they have been over exposed to heat and or by-products of the fire that could be poisonous and carcinogenic. Heads-up displays that could be used to present data such as air pressure, communication channels, building layout, and integration of the TIC to enhance visuals and displays, could help to direct a firefighter out of a risky building via the quickest route.

Although these new technologies are exciting and currently under development, the installation of the proposed systems brings another challenge to the fire service that needs to be investigated upon. The question is – who will run these systems? Today, it is easy to say that fire service agencies are not technology companies. This will need to drastically change as they will soon be inundated with a flood of data received from firefighters and other emergency responders wearing smart technology. Information systems will need massive amounts of data to run the new and smart technology effectively and efficiently. This data will need to be verified and updated frequently. Incorrect data could cost the life of a member of public or the life of an emergency responder.

Communication networks to support the real-time needs of the data requirements will need to be stronger than ever, build with considerable redundancy and system backups so that down time is minimal. Consider the outcry when an airport is unable to book passengers for flights because the computer booking system is not working, or the outpour of public dissatisfaction because trains are running late due to a technical fault. Having to reboot the system during the smallest of emergencies would be totally unacceptable to the public and emergency responders alike.

Further considerations need to be given to the emergency responders as there is a possibility that they will be swamped by a mass of data. Emergency situations are not straightforward; every event is different. In order to fully maintain these systems, the fire service will need to create new teams, with different skills, to maintain the database supporting the integrated systems.

Looking forward, new generation firefighters will cope better than the current generation of firefighters as they will be more familiar with the smart technology systems due to exposure in their childhood. First-person action games will help younger generations train their brain to cope with the multiple notifications of information. The fire service will need to consider their thirst for information, and how to maintain the information in formats that are quick to comprehend across all generations. Not having this considered could drive a wedge between the generations of firefighters who embrace the new technology and those who resist or find difficulties to keep up.

Training programmes will need to ensure that more than just the physical aspect of firefighting is taught. Information technology systems to be used in the field should also be introduced and taught to new firefighters. It will be more complex than merely logging into the Intranet system to check emails and perform administrative functions, such as to apply for leave. The public and government will demand that every active responder and support officer is more than competent in the use of the system, especially if it is life critical. Firefighters on their first day out of the training college will need to know how to use and interact with all the system requirements. Their lives and the lives of others will depend on it.

The responsibility of the fire service for the health and safety of its firefighters is what keeps the existing personnel around. An exposure to a chemical today could lead to long-term health consequences that would only arise in years to come. Data on firefighters' health during and after incidents is becoming an essential record that will need to be always maintained.

The fire service will also need to consider how new technology will impact the working environment of the retained, part-time, and volunteer firefighters. Globally, volunteers make up the majority of firefighters. In 2015, the NFPA reported that 70% of all firefighters in the USA are volunteers. [4] Other reports suggest that Germany has close to 97%, and Australia – over 60%. This brings about enormous challenges for training and operational integration as these systems should not be held for full-time responders only.

There is a possibility that information could overload emergency responders, and cause distraction and loss of situational awareness regarding their surrounding environment, potentially leading to higher risk. There are plenty of examples of people getting "stuck in the data", and not working in or with the environment around them. For instance, commercial airliners have crashed due to pilots being totally consumed with trying to work out if a warning light is broken or not. There are regular news featuring people attentively following their GPS such that they end up in rivers, drive down stairways into railway stations, and crash into buildings. There are also existing safety concerns with drivers and machinery operators getting distracted by their mobile phones while manoeuvring at work. Imagine the data that could be bombarding firefighters with heads-up displays in masks; the list is endless – from thermal imaging pictures, floor layouts, hydrant layouts, and air pressure, to directions, structural labels, and crew identification icons. That is a lot of data to sort through while working in zero visibility, dragging a heavy hose, and looking for potential victims in a building that one is likely never been in before.

Fires are quicker and have higher potential thermal output than ever before. This will only continue to increase as household and industrial furniture and fitting are made with new and advanced plastics, leading to increased energy release when exposed to heat, and increased rate of fire spread. Firefighting will always be dynamic, and it will become more dynamic into the future.

Companies spend a lot of time and effort to listen and determine what the fire service wants. The goal of any new product on the market is to fit the users' need as close as possible. It is impossible to create the perfect product for each fire service, and it requires work from both the end user and the manufacturer to create the best match.

The Best of Today's Technology!

Reviewing the technology available currently, there is a number of systems that promote safety and streamline a firefighter's job to help them meet their mission of protecting life and property.

In recent years, the cost and application of technology for TIC has greatly improved. This improvement means that the fire service can now afford to have a TIC in every truck. Future development will see TIC mounted on as part of a combined system on firefighters. It would either be placed on the helmet, mask, or possibly the SCBA.

The most important thing with a TIC is the image quality (refer to Figure 1). All the other features are just good to have, as firefighters will need the clearest quality possible. A quick glance at the screen is all the time a firefighter has. In this moment, the TIC user needs to determine a few important facts. They need to clearly see how big the space is that they are moving into, including the roof of the structure, the floor, and the walls. This will help determine the size of the room which will help them to understand the size of the area that needs to be searched, and if they have the resources to successfully search the area.

Figure 1: Image of thermal variation between fire source and firefighter

Beyond this information, the firefighter needs to clearly see two other pieces of information in the image – the location of the fire and the location of people in that space. That could be their fellow firefighters or victims. The TIC needs to be of the quality that will provide the responder the ability to clearly see both a human body and a fire in very close vicinity. If the TIC is not able to see past the fire, because it has flared out from all the energy released from the fire, it could mean that a victim at greatest risk would be missed. Testing of the TIC should be done in the most basic mode, and in very hot and cold scenarios ideally. A high-quality TIC will also help firefighter see air tracks and air movement which will help them identify the location of the fire, and can back track against the flow of the hot air to find the seat of the fire.

Figure 2: A Dräger FPS COM 7000 communications module added to a Dräger FPS7000 mask

Clear, concise, and simple communications in every aspect of life are essential. Mis-communication in a social setting can lead to an awkward situation but in an emergency situation, it can lead to something far dire. The ability to link firefighters so that they can have the operational conversations they need to have, but would not need to block critical radio channels by using their command radios, is essential. In Mask Communications Systems (refer to Figures 2 and 3), it links the firefighter through low frequency radio similar to Bluetooth and household modems. If the firefighter is on the same channel with another firefighter in close proximity, they will be able to directly speak to each other clearly.

Figure 3: Firefighters with Quick Connect facemasks attached to their helmets

There is also a system that allows the SCBA face mask to be connected to the firefighters' helmet. Such an innovation allows the donning process to be dramatically simplified as it removes the need for the firefighter to take off their helmet to don their face mask, resulting in time reduction, and allowing firefighters more flexibility on when that can "start-up".

The majority of the fire service agencies in ASEAN are still using procedures that were developed from the British Fire Service manual in the 1940s and 1950s. These procedures, which have stood the test of time, are an excellent base for all firefighters and will last well into the coming generations of firefighters. Donning of a SCBA is still expected to take a firefighter 60 seconds. That procedure was set in place when firefighter did not wear gloves but wore woollen tunics and had helmets made of brass or cork. Times have changed! What these procedures do not take into account is that today's firefighters are now dressed in turnout jackets that are thicker and bulkier, with flash hoods, thick gloves, and other accessories like, radios and forcible entry tools to contend with.

Conclusion

The next few years will see exciting times for the fire service and manufacturers alike. Keeping up with the changes ahead will be a challenge for both. New technology does not always match to old procedures. The fire service is going to need to rethink their current operation procedures and business models. Manufacturers are going to need to come up with newly-designed business models to support their customers. The fire service has always been seen as the total authority when it comes to procedures, and how equipment is used. This is dramatically changing and the fire service should be looking to engage directly with the manufacturer at the highest level to create partnerships and formulate the best integration path for new technology into their business in order to have the best solution and fulfil all the primary goal of protecting life and property.

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EDITORIAL PREVIEW

In an emergency cardiac arrest situation, every second counts.

The myResponder Application (mRa) is a digital platform that engages the assistance of the community in emergency response. Aligned with SCDF's vision, the mRa is sophisticated in its conceptualization as it adopts a bespoke approach in Agile software development principles.

This article tells the story of how the mRa was incepted, using the Scrum project management framework under the Agile approach. There is a unique section dedicated to a glossary of terms in this article.

The Editorial Board encourages all Singaporeans to download the mRa, and register themselves as Community First Responders (CFRs). CFRs not trained in CPR or AED skills can still contribute by retrieving AEDs, guiding the ambulance to the scene, or performing chest compressions as guided by the SCDF's 995 Operations Centre Specialists.

SCDF is putting out a call to action to all Singaporeans to play their part to safeguard their nation and community by being a part of the mRa and CFR scheme. Interested persons can contact the Editorial Board for more information.

THE MYRESPONDER SMARTPHONE APPLICATION – AN AGILE APPROACH

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Introduction

In Singapore, there is an average of 300 suspected cardiac arrest cases every month. Survival rate decreases by 10% for every minute where life-saving interventions are not applied. In Singapore, the survival rate for witnessed Out-of-Hospital Cardiac Arrest (OHCA) incidents is approximately 13.8%, one of the lowest among developed cities in the world.

The Case for Community Intervention

While SCDF constantly strives to respond expeditiously to every incident, critical life-saving time is lost due to the time needed to travel down to the incident. As such, the case for community response became urgent. SCDF recognised that there was a dire need for community bystanders to come forward to swiftly revive cardiac arrest casualties in the interim moments before SCDF's arrival. This timely intervention would make the difference, significantly enhancing the survival rates of the casualty.

This urgency is compounded as a sizable portion of Singapore's population is aging. A new paradigm-shifting approach to life-saving had to be found, otherwise the future demand load on SCDF's limited fleet of assets may become impossible to bear.

Co-Partnering with the Community

As a result, SCDF embarked upon a transformation journey in 2013, with the aim of achieving its vision of "A Nation of Lifesavers" by 2025. A key pillar of this vision involved a concerted effort to "Engage and Empower the Community", where SCDF aimed to facilitate the community's transition from "concerned bystander" to "active responder". After undergoing the appropriate training, the community would serve as a first-tier response to emergency incidents, prior to SCDF's arrival. By alerting and empowering the community to respond to incidents within their immediate vicinity, response times would be cut dramatically, thereby enhancing survival rates.

Enabling Technology: Geolocation and the Ubiquitous Smartphone

It was against this backdrop that SCDF conceived the idea of the myResponder application (mRa).

Leveraging upon Singapore's robust mobile 4G network, high penetration rates of smartphone adoption, and the geolocation technologies embedded within each device, the idea was to develop a smartphone application to have SCDF Operations Centre send out an alert to crowdsource volunteers to respond to OHCA cases within their vicinity. Integrated within the mRa would be a database and map of nearby Automated External Defibrillators (AEDs) for the volunteer to retrieve and bring to the casualty. The mRa thus expeditiously brings together the three vital components of cardiac arrest response into an effective, integrated whole: (1) the victim; (2) Community Responder; and (3) the nearest available AED.

SCDF's adoption of the crowdsourcing concept harnesses the power of the community and the social media savviness of the local population towards enhancing national safety levels.

The myResponder Application: A Product Development Perspective for Community-Based Software Development

With this idea, the SCDF project team set to work. They surveyed similar products in the market but discovered that Commercial Off-the-Shelf (COTS) solutions could not adequately meet the Force's specific operational requirements. They then decided to adopt a bespoke approach to develop the app. Decidedly, the team chose to steep the development of the app in ***Agile software development*** principles usually not associated with the traditional paradigm within which the public sector operates.[1][2] Many aspects of this process adhere to what is termed as a ***Scrum*** process. This process is separated into 3 phases – the pre-game phase, development phase, and post-game phase.

Pre-Game Phase

With the high level system architecture (such as backend systems and data infrastructure) in place in April 2014, the next step was to move to product development. The Government Digital Services Team from the (then) Infocomm Development Authority (IDA) of Singapore was engaged to develop the app in close collaboration with SCDF's project team. IDA provided the technical expertise and service while SCDF, as the project leader, provided a ***product backlog*** and business domain expertise (i.e. as the national service provider of emergency medical services).

Development Phase

The app was then developed through a series of ***sprints*** that quickly tested, reviewed, validated (or invalidated) and iterated features that were incorporated. Through the series of sprints, key features were prioritised and tested, and quickly discarded if found to be non-essential. Unexpected issues by test-users that were encountered were also swiftly communicated and addressed through close collaboration between the development partners. Simultaneously, SCDF organised workshops and discussions with various stakeholders (e.g. SCDF paramedics, '995' call takers, and members of public) to provide their feedback to fine-tune the user-experience from their perspectives. This allowed the project team to focus on the essential aspects of the app (such as the notification of nearby responders and the display of nearby AEDs) through validated learning.

By November 2014, a beta version of mRa was launched to a group of SCDF users to assess its effectiveness, and to identify further areas for refinement (such as optimising app performance to reduce battery drain). Through feedback from the beta launch, the project team fine-tuned the user experience further to reduce the barriers that may have prevented members of public from coming on-board as a Community First Responder (CFR). After this feverish development period, mRa was officially launched at SCDF Workplan Seminar 2015.

Even after its official launch, the project team continuously iterated and improved the product, inviting CFRs for a workshop to understand their experience using the app, and to solicit feedback on improvements. Following the launch, the next challenge was to scale the usage of the app to truly realise the vision of community first response, and "a Nation of Lifesavers". The feedback and user experience reviews brought about improvements in user interface for receiving notifications, customisable notification alert tones, and improvements to viewing AEDs on the maps.

Post-Game Phase

Following the complete development and roll-out of the app, post-development tasks, such as integration into existing systems for smooth deployment followed. As a later phase to on-board a larger mass of users, SCDF collaborated with Temasek Cares and SMRT on the AED-on-Wheels programme that enrols taxi drivers as volunteers, and trains them on CPR and the use of AEDs (refer to Figure 1). In addition, the taxis are outfitted with AEDs which means participating taxi drivers can be notified of the incident within a 1.5km radius through the app, be quickly dispatched to the incident location, and arrive at the incident scene armed with the AED to begin resuscitation. In all, there were 3 subsequent major releases of the mobile app, which contained new features and enhancements, in February 2016, June 2016 and September 2016.

Figure 1: Taxi driver on-board the AED-on-Wheels programme

GLOSSARY OF TERMS

Agile software development

Agile methodology is not a strict prescriptive set of rules for software development, but rather an accumulation of principles which is generally the common denominator among many of the more specific development frameworks that or are deemed to be Agile methods. Among other definitions in academia since the publication of the 'Agile Manifesto' in 2001[3], a proposed definition is that when software development is incremental, cooperative (with customers and developers), straightforward (to learn) and adaptive, it is considered to have gone through some form of instruction in Agile software development. For further reference, see http://agilemanifesto.org

Scrum

Scrum is one of many Agile software development methods that has emerged from the experience from practitioners. It is generally an adaptive, self-organising product development process, whose name takes inspiration from the strategy in the game of rugby.[4] The Scrum process includes 3 phases: pre-game, development and post-game, each with a suite of sub-processes that a software development team adheres to within a strict timeline.

While the Scrum framework has been widely used, it has been recognised as being more of a project management framework, facilitating an effective software development process. The actual means of technical software development are not specified by the Scrum framework; thus, it is often used in tandem with other Agile methods which the project nature dictates.

Product backlog

The product backlog is a set of items that defines all the required features based on the knowledge held by the project team at the onset of the project. Thus, it defines the work included within the scope of the project. As the project develops, new features emerge and are prioritised, and the product backlog is constantly refreshed. The project team leader is typically in charge of making decisions with regards to the product backlog.

Sprints

A sprint is a sub-process typically found within the "development phase" of the Scrum framework. It is the procedure of adapting to changing externalities to iterate and produce a new and actionable increment to the product for further testing. Sprints are deliberately short in duration, typically lasting for about 30 days, and littered with meetings to ensure that the entire team is in sync with the iterations.

Impact of the myResponder App

To date, the mRa has seen close to 100,000 downloads across both Android and iOS devices (refer to Figure 2). Close to 35,000 Singaporeans have registered themselves to be CFRs (refer to Figure 3). To date, these CFRs have answered the call 4,500 times and responded to incidents.

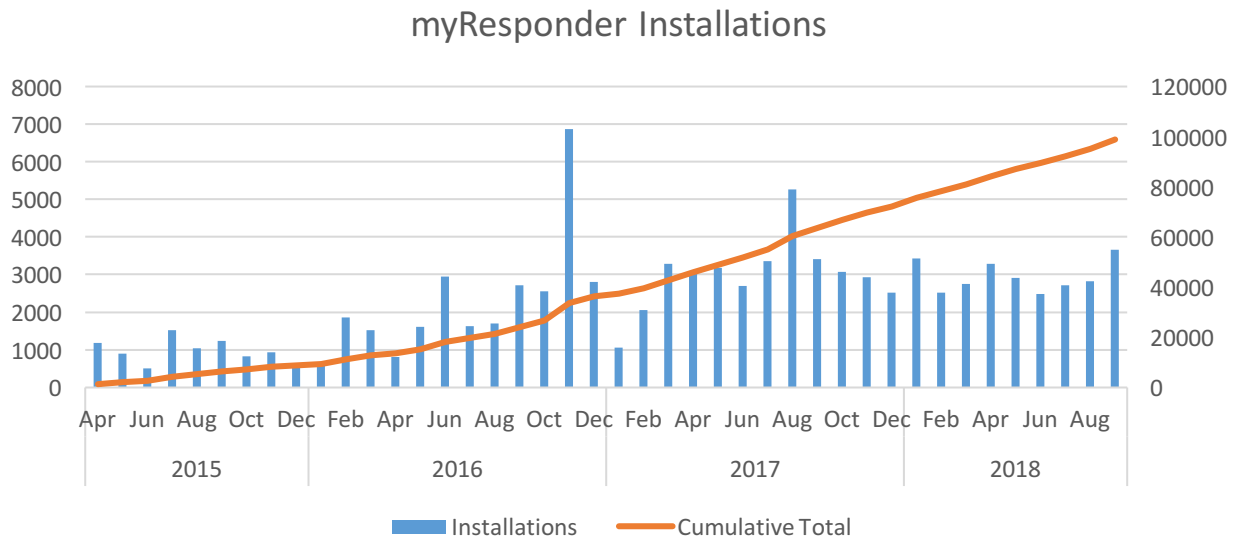

Figure 2: Installations of the myResponder app on Smartphones have trended upwards since the app was launched.

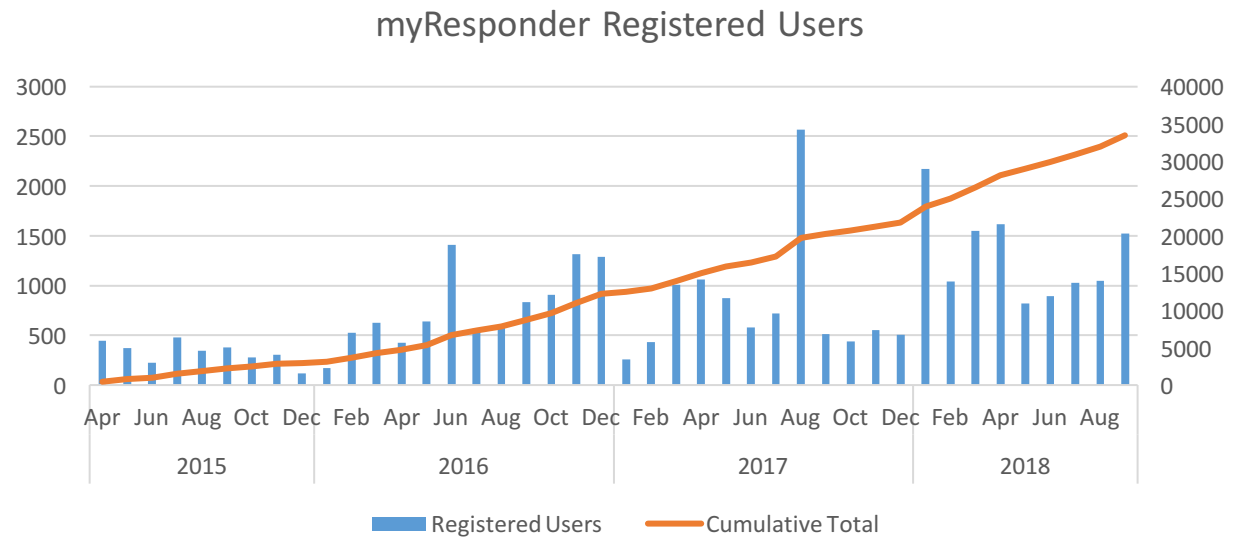

Figure 3: The number of users registered to be notified via the app has steadily increased.

Success Story 1

In January 2016, Madam Michelle Lim was having breakfast when she received a notification from the mRa alerting her to a cardiac arrest case in her immediate vicinity. She left her table and hurried to the casualty's location. When she arrived, a bystander was already performing chest compressions on the victim. She took over and continued chest compressions on the man until the SCDF Team arrived, reviving him with an AED. The casualty was admitted to hospital, and was discharged six days later.

Success Story 2

In September 2016, William, who was a registered Community First Responder, had just ended work and was on his way home when the app notified him of a nearby case of cardiac arrest. A SCDF Firebiker had already arrived, and together, they administered help and CPR to the casualty. The casualty was revived and conveyed to Khoo Teck Puat Hospital and was discharged soon after.

Success Story 3

In December 2016, Kenneth, an off-duty SCDF responder, was alerted by the app on a case that occured a few blocks away from his location. Upon arriving at the casualty, he saw a woman performing telephone CPR on the casualty. Kenneth took over and continued CPR before the arrival of the SCDF Team. Patientwas then stabilised and conveyed to Khoo Teck Puat Hospital. Patient was discharged soon after.

SCDF believes that the mRa's full potential remains to be unlocked. With increased public awareness for the mRa, and the resultant expansion of the CFR network to one of greater density through increased signups, the mRa is poised to be a key enabler towards shepherding in SCDF's vision of "A Nation of Lifesavers".

Next Stage of Development

In 2018, SCDF extended the CFR scheme to allow the community to mitigate against minor rubbish fires. The mRa was enhanced with an additional module to alert the community to minor fires in their area, and allow SCDF Operations Centre to monitor their response to minor fires. Significantly, the mRa was also enhanced to allow them to provide first-arrival information to SCDF Operations Centre in the form of pictures and videos. This allows SCDF to better sense-make, calibrate, and deploy a sharper response to mitigate against the incident. The mRa will continue to evolve according to new needs that arise, and are surfaced during its deployment.

Conclusion

The Agile software development methodology is celebrated by start-ups for its speed of developing products validated through user reviews. SCDF's experience in adopting the Agile software development method – in this case, using a Scrum project management framework – has proven to be efficient and effective in developing an outward-facing mobile application. Endorsement by senior leadership, close collaboration with partners and stakeholders, as well as a willingness to adopt new product development frameworks in Agile also contributed to the process. The resultant application is a user-centric mobile app that is a highly integral and integrated part of SCDF's concept of operations. Based on user feedback, metrics of registration rates, as well as anecdotal recounts of successful and meaningful outcomes, the app is truly a catalyst to usher in SCDF's vision of "A Nation of Lifesavers".

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BE A COMMUNITY FIRST RESPONDER TODAY

SCDF is putting out a call to action to all Singaporeans to play their part to safeguard their nation and community. An incident could strike at any time, and it is important for Singaporeans to be prepared against all eventualities. SCDF encourages all Singaporeans to download the myResponder app and register themselves as CFRs. CFRs not trained in CPR or AED skills can still contribute by retrieving AEDs, guiding the ambulance to the scene, or performing chest compressions as guided by the SCDF's 995 Operations Centre Specialists. In addition, those who download the app can also choose to alert SCDF Operations Centre of an incident via the app, which would send their geolocation to allow SCDF dispatchers to quickly discern the current location.

Registering to be a CFR is easy. Just follow the simple steps below:

1. Download the myResponder application from:

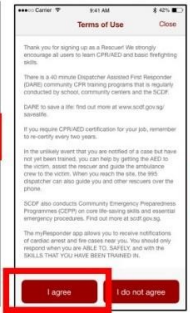
Apple App Store

Android Google Play Store

2. Follow the screen shots below:

Choose Sign Up

Read and Agree to Terms of Use



Inclusion of SMS OTP as a sign-up option

For SMS OTP, enter particulars

Verify the SMS OTP

Ensure Notifications are turned ON

3. Read the tutorial and FAQs in the app, and you are all set to be a CFR!

EDITORIAL PREVIEW

Traditional methods of collecting data for gaining insights have always taken a significant amount of time and resources. It is of no doubt that technology has since made data collection much easier and cost-effective. In broad terms, Data Analytics (DA) is the process of examining raw data sets, via a specialised system, to draw conclusions about the information they contain.

In this article, SCDF shares about harnessing the potential of DA as a competitive and sustainable advantage to identify possible issues and develop appropriate solutions. With the project on Dynamic Resource Optimisation (DRO), SCDF has stepped into the game of converging big data and machine learning.

The article also discusses about SCDF's future action plans in the sphere of advancing DA, especially in its drive to weave a data-centric mindset into the Force's structure and cultural fabric. Through this article, the Editorial Board hopes to impress upon readers an overview of the DA journey undertaken by SCDF. Interested persons who need further information on SCDF's DA plans can contact the Editorial Board.

UNLOCKING HIGHER PERFORMANCE WITH DATA ANALYTICS

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Introduction

Data analytics adoption in the world reached 53% in 2017, up from 17% in 2015.[1] Enhanced organisational reporting, advanced visualisation dashboards for end-user "self-service", and data warehousing are the top strategic applications arising from advancements in data analytics.

The most important reason driving the rise of data analytics is a push towards evidence-based decision-making. Instead of relying on the intuition of key-stakeholders which may be subjected to cognitive biases, insights extracted from data enhances decision-making for them, thereby contributing toward greater business performance.

Data Analytics (DA) as a Strategic Enabler

The ability to drive critical and accurate insights with speed across a variety of data sets and channels (e.g. web portals, internal systems, mobile computers, etc.) can dramatically improve the formulation of government policies and practices. Well-crafted practical actions to improve service delivery to customers can also be done, deriving increased value to all stakeholders.

Opportunities Abound

The digitisation of virtually "everything" now creates new types of large and real-time data across a broad range of industries. Much of this is non-standard data, such as streaming, geospatial, or sensor-generated data that does not fit neatly into traditional and structured data warehouses. Modern computing has evolved to a point where it can handle huge amounts of data from multiple platforms concurrently (3 Vs of big data: Volume, Variety, and Velocity).[2] Additionally, advanced analytics technologies and techniques have become increasingly available for organisations, who apply them to extract insights from data with previously unachievable levels of sophistication, speed, and accuracy.

Data Analytics Transform the Way to Operate

To attain the vision of "A Nation of Lifesavers", SCDF formulated three strategic outcomes: (1) Sharpen Operational Edge – where resource constraints are efficiently managed and operational methods are enhanced in its effectiveness; (2) Engage and Empower the Community – where joint-response intervention with the community to emergency incidents is prioritized and pivotal; and (3) Institute Safety and Public Protection – where SCDF continues to work with partners to promote the ethos of fire safety and prevention to the community.

To codify and establish the desired outcomes for DA, SCDF scoped its future DA efforts into 5 business clusters:

Business Cluster	Desired Outcomes & Objectives
Sharpen Operational Edge	Deep understanding of operational data to optimise the live deployment of limited resources Amalgamate and automatic sense-making of sensor data from island-wide network of sensors to enhance situational awareness
Enable and Empower The Community	Volunteer profiling to allocate limited training resource to target communities of need and improve community participation Deepen understanding of user emergency service needs to design upstream prevention
Institute Safety and Public Protection	Risk-based assessment to allocate limited enforcement resources to target high-risk premises Identify hazardous trends for preventive action
Organisational Administration	Full understanding of assets and transactions to highlight anomalies and enhance control and policy planning
Human Resource	Individual profiling for targeted recruitment, retention, and continuous training

DA will surface out insights from the vast data that reside within SCDF's operational systems, allowing the Force to sharpen its efforts in carrying out its life-saving mission. Previously unknown insights could be surfaced, illuminating interconnections and trends that SCDF was once unaware of, or even pave the pathways that could lead to the next operational breakthrough for the Force.

Dynamic Resource Optimisation (DRO)

SCDF has seen success in some of its initial DA efforts.

SCDF's Dynamic Resource Optimisation (DRO) aims to address a fundamental Emergency Medical Service (EMS) operational issue – ambulance placement. Optimal placement of an ambulance would minimise the response time needed in attending to EMS incidents. Traditionally, ambulances were placed in accordance to Key Performance Indicators (KPIs), such as response time and ambulance load across individual bases. SCDF's plan was to apply optimisation tools to forward deploy ambulances to anticipated areas of heightened activity during peak hours, in order to lower response times. SCDF collaborated with the Singapore Management University (SMU) to develop the DRO. Since the DRO's completion in September 2017, SCDF has been using the DRO to support its ambulance deployment decisions (refer to Figure 1). Results have been encouraging with the deployment configuration as ambulances are better able to meet the 11-min response time KPI by 3.7% (i.e. According to the recommendations generated by the DRO, SCDF was able to respond to about 7000 more calls within 11-min in 2017). SCDF has plans to further enhance the DRO in the future.

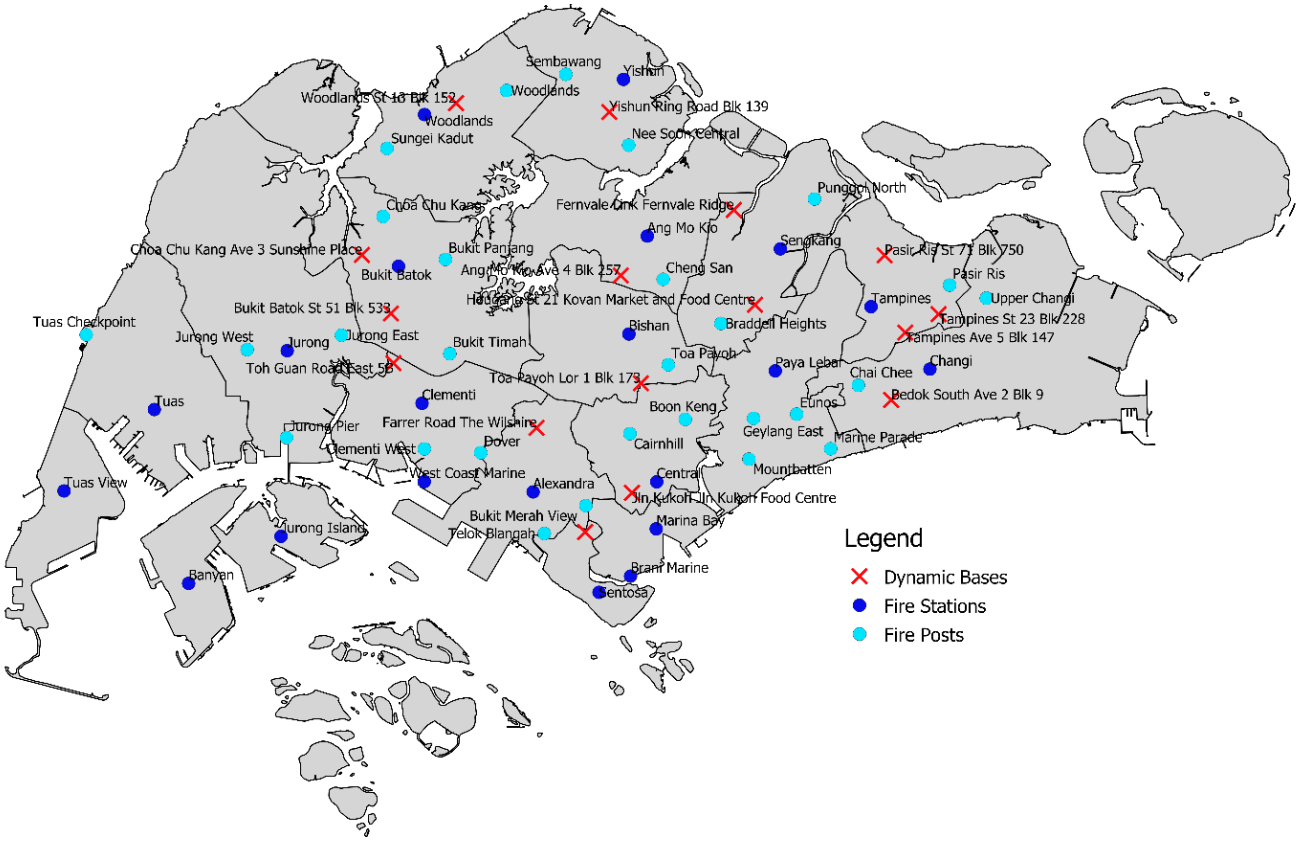

Figure 1: Recommendation on Locations of Dynamic Bases generated by the DRO

SCDF also applied DA to its payment and claim processes. SCDF found that DA allowed it to run entire datasets to surface outliers and identify areas of weakness. This was a significant improvement over its previous approach of running analysis based on data samples, which may or may not have surfaced out issues. Results gathered from the DA exercise has allowed SCDF to implement targeted measures to improve process efficiency, ranging from short-term measures (e.g. periodic post-payment analytics check, review of work processes, and focused education) to longer-term measures.

Based on the highly encouraging results from its initial efforts, SCDF believes that DA has more to offer to the Force.

Challenges Ahead, but Nothing Insurmountable

DA presents a rich field of opportunities because of the diverse array of meaningful problem statements that can be surfaced for further investigation.

The promise of achieving significant and measurable value from DA can only be realised if organisations put into place an information foundation that supports the rapidly growing volume and variety of data. [3] Data infrastructures will need to be integrated, scalable, secure, and governed according to agreed-upon standards. The inability to connect data across organisational and department silos remain a constant challenge. Additionally, storage infrastructure and high-capacity data warehouses will be needed. Data security and governance is of vital importance, and the added legal, ethical, and regulatory considerations add new risks and expand the potential for public missteps.

Moving Forward

To take full advantage of DA, SCDF will first need to transform itself digitally. Legacy systems and work processes across the entire Force that are currently administered via hardcopy documents will need to be digitised. Data silos would need to be demolished and integrated. Digital pathways that ensure the fluidity of data transmission across the Force to requestors will need to be laid. A robust enterprise-based search engine would need to be applied over all the different databases in order for data to be easily searched and accessed. Data security policies and measures would need to be established to safeguard against unauthorised use.

Moreover, the sweeping changes brought forth by digital transformation will change the way staff work, so change management strategies will need to be applied to help cope through the disruptive transition. As such, SCDF will be undertaking a full-scale digital transformation effort to achieve end-to-end digitalisation of work processes, and facilitate change management strategies for staff to embrace a digital future. SCDF believes that this effort would unlock opportunities for digital transformation, causing paradigm shifts in the way it operates, and possibly leading to quantum leaps in performance.

The two examples illustrated earlier indicate the success stories that have arisen from SCDF's nascent forays into the field of DA. A comprehensive and holistic DA strategy will need to be developed to allow the Force to leverage upon the benefits of DA. Doing so will involve a Force-wide, deep-dive exercise to review SCDF's numerous work functions and determine which areas DA should be applied to derive maximum gains.

Conclusion

In today's digital economy, data is a strategic asset that can be used to better achieve organisational goals. As such, data should be included in strategic planning, enterprise architecture, and day-to-day operations of any organisation. Hidden within the vast mounds of data lie new actionable information – facts, relationships, indicators, trends, interconnections, etc. – that could not be practically discovered in the past, or simply did not exist before. This new information, effectively captured, managed, and analysed, has the power to change organisations.

SCDF hopes to democratise the use of data across SCDF. While analytics personnel in HQ could continue to process data to be shared Force-wide, less-advanced users of DA can rely on the many self-service dash boarding tools to run test cases surrounding operations and other areas.

SCDF stands ready to leverage upon its data, and is poised to act upon the new insights to transform the way we operate.

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EDITORIAL PREVIEW

A majority of firefighters not trained in shipboard firefighting think of a vessel fire in the same way as a structure fire. Vessels, however are not just structures, but miniature cities floating on water. They are a fuel storage farm, a power plant with high voltage, a multi-story hotel, and a warehouse with all kinds of commodities – all in one. Shipboard firefighting is more than putting water on fire.

In preparation for the future landscape, SCDF embarked on the journey into the maritime domain in 2012. The maritime realm was traditionally under the purview of the Maritime and Ports Authority of Singapore (MPA). Today, with about six years of marine operations built from scratch, SCDF is better equipped to manage the rigours of shipboard firefighting. This article summarizes the journey SCDF had took to cope with the threats introduced by the dynamic maritime environment. The journey definitely doesn't end at this article; interested persons who wish to find out more may contact the Editorial Board.

CHARTING SCDF'S MARITIME JOURNEY

MAJ Neo Jia Qi, Commander West Coast Marine Fire Station, Marine Command
Singapore Civil Defence Force

Figure 1: A symbolic handing and taking over ceremony was held at West Coast Pier, where a scale model of the MPA emergency response vessel Api-Api was handed to the first commander of SCDF MC, then-LTC Derek Tan.

Introduction

As part of Singapore's continued efforts to streamline and optimise the deployment of government resources and to enhance maritime firefighting coverage within Singapore Waters, the marine firefighting function was handed over on 1 April 2012 from the Maritime and Port Authority (MPA) to the national authority for firefighting; the SCDF. This marked the birth of the youngest unit in SCDF, the SCDF Marine Command (SCDF MC).

With the take-over (refer to Figure 1), SCDF was tasked with the new responsibilities to handle marine fires within Singapore Waters. To allow SCDF to operate on the waters immediately, Two MPA emergency response crafts, Api-Api 1 and Api-Api 2, and the MPA emergency response base at West Coast were asset transferred to SCDF. A total of 22 MPA marine emergency assistants and officers were also transferred to SCDF under the Home Affairs Uniformed Scheme (HUS) to augment SCDF's manpower strength.

Api-Api 1 and Api-Api 2 were sent for major retrofitting and renamed as Firefighter 1 and Firefighter 2 on 12 March 2013 during a special ceremony at Brani. The vessels were also re-designated as Marine Fire Vessels (MFVs). The ground breaking ceremony for a brand new marine base at Brani was also conducted at the same time, graced by then 2nd Minister for Home Affairs and Trade and Industry, Mr S. Iswaran (refer to Figure 2). The new marine base at Brani was completed in 2014 and currently houses two important facilities, HQ SCDF MC and Brani Marine Fire Station.

Figure 2: Renaming of Vessels and Ground Breaking Ceremony of Brani Marine Base on 12 March 2013 by Mr and Mrs S Iswaran.

Training and Preparation

The first responders in SCDF MC are Marine Specialists. The skills and knowledge required of Marine Specialists are multi-faceted. Marine Firefighting, Complex Rescue, Height Rescue, Emergency Medical First Aid, Hazardous Materials (HazMat) and Seamanship Skills (Boat Handling, Navigation and Marine Engineering) are all critical core skills that are integral to the success of every marine emergency incident.

To prepare the personnel, SCDF MC has in place a training roadmap and certification processes (refer to Figure 3) for every officer to ensure that they develop the necessary skills and competencies to carry out the job required of them.

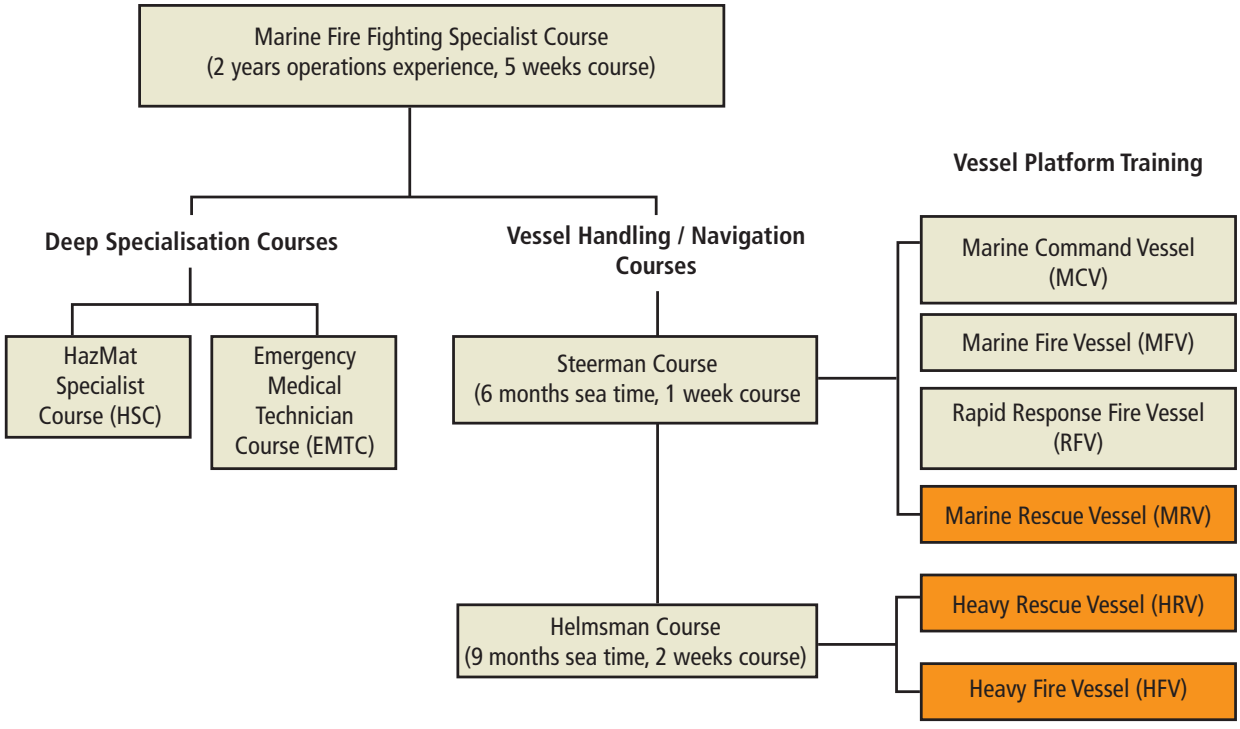

Figure 3: SCDF MC's Training Roadmap (Orange boxes denote future vessel platforms).

Every Marine Specialist is required to undergo a gruelling five weeks Marine Firefighting Specialist Course, conducted by SCDF Civil Defence Academy (CDA) in partnership with Singapore Polytechnic's Singapore Maritime Academy, before posting to a marine fire station under SCDF MC. The course covers fundamental training in firefighting and rescue techniques and tactics in the maritime context, as well as personal survival skills in a shipboard environment (refer to Figure 4).

Subsequently, the Marine Specialists will be sent for various advanced courses such as Steersman and Emergency Medical Technician (EMT) courses to ensure that they are equipped with the necessary knowledge and skills to provide well-rounded emergency response out at sea. EMT and HazMat Specialist training are conducted at SCDF CDA, while boat handling and navigation training are provided jointly by Police Coast Guard (PCG) as well as SCDF MC's Operations and Training Branch, with the licensing administered by MPA.

To ensure that capabilities are in line and up to date with international marine firefighting standards, SCDF MC have also conducted benchmarking study visits to renowned fire services globally, as well as nominated officers to participate in relevant training overseas. Some of the fire services that SCDF have visited include Hong Kong Fire Services Department, Fire Department of New York City, Los Angeles Fire Department and Bataillon de marins-pompiers de Marseille. SCDF MC officers have also attended training conducted in the United States of America and Hong Kong.

Figure 4: Marine Firefighting Specialist Course involving training in firefighting and rescue techniques in maritime context.

Current Capabilities

Today, SCDF MC has two marine fire stations at West Coast and Brani, and its Division Headquarters co-located at Brani. There is also a Marine Fire Post co-located at Police Coast Guard Loyang Regional Base. The total manpower of the unit stands at approximately 140 strong, with three rotation shifts on operational standby 24/7.

The SCDF MC fleet includes two MFVs, two Rapid Response Fire Vessels (RFVs) and four Marine Command Vessels (MCVs) (refer to Figure 5). The MCVs are high speed craft that can deliver manpower and logistical supplies to the incident site quickly, while the RFVs are the latest vessels to join the SCDF MC fleet.

Commissioned by Minister for Home Affairs Mr K. Shanmugam on 3 May 2017, the RFV boasts unique facilities like a special Rescue Zone and Davit Cranes. The RFVs operate on high speed diesel engines and water jet propulsion systems which allow them to respond swiftly to incidents in all types of sea conditions.

Figure 5: (from left to right) MFV, MCV and RFV makes the SCDF MC fleet to respond to a wide array of incidents in the maritime environment.

The idea of RFV was conceived back in 2013, when SCDF MC officers realised that the heavy duty MFV, while powerful, had limitations to its response as it was slow moving and required relatively deep waters to operate in (Under Keel Clearance of 3m for safe passage). SCDF needed a smaller, faster vessel platform that is more flexible and nimble. This form of finesse will allow the vessel to manage a wider array of incidents in maritime environments. SCDF MC worked closely with PCG to develop the RFV, as PCG vessels, due to their nature of work in crime interdiction and interception, are designed to be swift in open waters and possess the same attributes that SCDF MC required of the RFV.

The RFV measures 20 metres in length, with a shallow draft of one metre. This vessel size allows the RFV to operate in most environments within Singapore Waters, including the coastal search operations where shallow waters were often not suitable for MFV to navigate. RFV is equipped with twin engines, each producing a maximum output of 1626.9BHP at 2300RPM and water jet propulsions, as shown in Table 1. These engines allow the vessel to travel at a top speed of 40knots (approx. 74km/h), which is three times the speed of MFV.

RFV Specifications	
Length Overall	20.25 m
Beam	4.8 m
Full Load Displacement	41.40 MT
Top Speed	40 knots
Endurance	250nm or 24 hours continuous operation
Complement	4 men
Propulsion	Water Jet
Engine	Twin Diesel Engines, 1626.9BHP @ 2300RPM each
Fire Fighting Capacity	2 x Fire Pump each 415m^3/hr 2 x Fire Monitor each 300m^3/hr

Table 1: Specifications of RFV.

Figure 6: Side profile of the RFV illustrating its deliberate design to facilitate water rescue.

The RFV is also fitted with a rescue zone (refer to Figure 7), which is a recessed area at both sides of the vessel. The rescue zone was a SCDF innovation project that was designed by SCDF responders to improve water rescue operations. It is designed to allow rescuers to gain access to the water surface level to facilitate water rescue. The rescue zone is also equipped with a davit crane (refer to Figure 8) that helps the rescuers to haul up casualties.

Future Developments

Over the next couple of years, SCDF MC will continue to develop new vessels with more advanced technologies to complement its firefighting fleet. three more state-of-the-art heavy fire and rescue vessels will be constructed and delivered by 2019 (refer to Figure 9). Built locally in Singapore, these vessels will enhance the response capabilities of SCDF MC in its firefighting power, response speed, carrying capacity, *in-situ* and *ex-situ* Command, Control and Communications as well as HazMat capabilities.

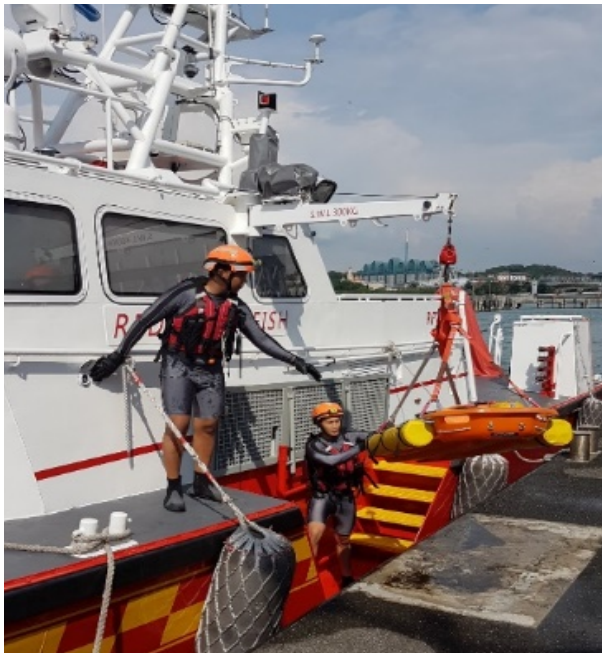

Figure 7: The rescue zone in operation during training.

Figure 8: (from left to right) 3-Dimensional Impressions of the Marine Rescue Vessel (MRV), Heavy Rescue Vessel (HRV) and Heavy Fire Vessel (HFV).

Plans to build a third marine fire station in the eastern side of Singapore and a marine outpost in the northeast of Singapore are also in the pipeline to provide a more comprehensive operational coverage on Singapore waters.

Conclusion

The vision of SCDF MC is to become a world class marine firefighting outfit, delivering top quality marine fire and rescue services within Singapore waters. Singapore is home to one of the busiest and most developed global hub ports in the world. It sees gross shipping tonnage that are perennially ranked top three in the world and housing a wide array of marine and offshore related services such as shipyards, container mega-ports and international cruise centres. It is imperative that SCDF keeps up with its service delivery to keep Singapore waters safe and secure, making the Port of Singapore still a vibrant location for marine trade and industry to flourish in many years to come.

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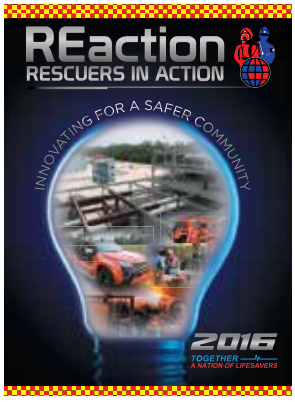

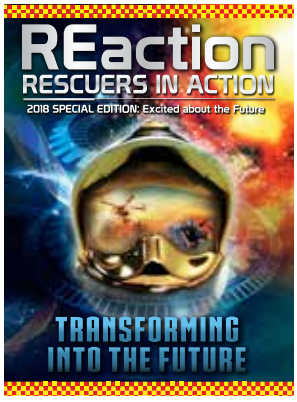

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