Submarine Rescue Capability and its Challenges

ABSTRACT

Providing rescue to the crew of a disabled submarine is of paramount concern to many submarine-operating nations. Various rescue systems are in operation around the world. In 2007, the Republic of Singapore Navy (RSN) acquired a rescue service through a Public–Private Partnership. With a locally based solution to achieve this time-critical mission, the rescue capability of the RSN has been greatly enhanced.

Dr Koh Hock Seng
Chew Yixin
Ng Xinyun

Submarine Rescue Capability and its Challenges

INTRODUCTION

On Tuesday 23 May 1939, USS Squalus, the newest fleet-type submarine at that time for the US Navy, was sailing out of the Portsmouth Navy Yard for her 19th test dive in the ocean. This was an important trial for the submarine before it could be deemed seaworthy to join the fleet. USS Squalus was required to complete an emergency battle descent – a 'crash test' – by dropping to a periscope depth of 50 feet (about 15 metres) within a minute. The trial started off well and USS Squalus descended smoothly and reached its target depth. However, the crew soon realised the engine rooms were flooding and within moments, the submarine sank off the Isles of Shoals beneath 243 feet (about 74 metres) of water (Maas, 1999).

"…[The] disaster was to hand Lloyd B. Maness a cruel duty. He was nearest the hatch which separated the flooding sections from the dry area. If he didn't slam shut that heavy metal door everybody on board might perish. Maness waited until the last possible moment, permitting the passage of a few men soaked by the incoming sea water. Then, as water poured through the hatchway… he slammed shut the door on the fate of those men aft."

The Register Guard, 24 May 1964

Of the 59 men on board, 33 were saved after a 40-hour rescue effort which would not have been possible without 'Swede' Charles Bowers Momsen's contraption of a large steel rescue chamber[1] as shown in Figure 1. First of its kind, the McCann Bell[2] allowed a collective rescue of the crew from the sunken submarine.

This article presents an overview of the developments in submarine rescue since the USS Squalus incident. The equipping of the Republic of Singapore Navy (RSN) with locally based rescue capability and the several challenges faced in submarine rescue efforts around the world today will also be discussed.

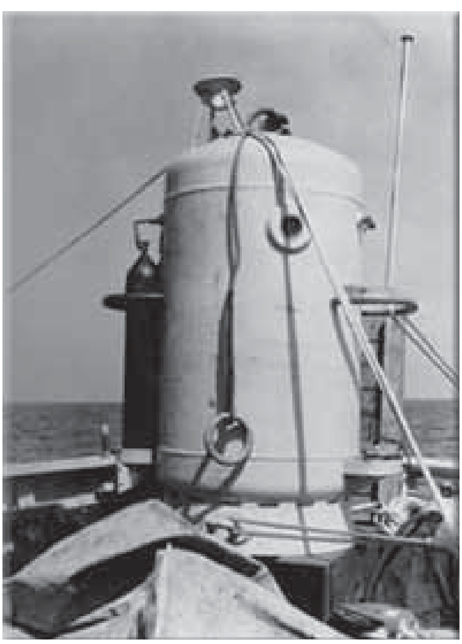

Figure 1. Rescue chamber based on Swede Momsen's design (Source of left image: University of New Hampshire Library)

CHANGING PERSPECTIVE – FROM ESCAPE TO RESCUE

"Unlike air crashes, submarine accidents frequently have survivors, which makes the imperative of developing rescue capabilities even more acute." (Goldstein & Murray, 2008)

After World War Two, new methods and approaches were adopted to boost the survivability of submarine crew. The traditional method of escape, where the crew of the distressed submarine (DISSUB) leaves the boat and reaches the surface without assistance, was replaced by aided ascent due to improvements in technology. However, there were limitations in both methods of escape. The chances of suffering from decompression illness remained high and neither provided protection to the submariner against the elements once he reached the surface. This was evident from the collision and sinking of HMS Truculent in 1950. All 72 crew members made it to the surface, but only 15 survived while the rest were lost at sea (according to the Royal Navy Submarine Museum). The success of the McCann Bell was a leap of improvement but proved to have its limits as well. The system could only operate in less turbulent seas and shallower operating depths as it required divers to secure guiding lines to the DISSUB along which the rescue chamber descended.

The sinking of USS Thresher in 1963, with all hands lost, was the trigger point for the US Navy to develop the Deep Submergence Rescue Vehicles (DSRV) to overcome the limitations of the McCann Bell (GlobalSecurity.org). Launched in January 1970, the first DSRV[3] by the US Navy had a bigger rescue capacity and was able to reach deeper depths than the McCann Bell. It was transported to the site of the DISSUB by riding on a mother submarine in 'piggy-back' style as illustrated in Figure 2.

Other nations like the UK drew inspiration from the commercial diver lockout submersibles that were already in use in the early 1970s in the North Sea oil and gas fields (Sussman, 2000a). In 1983, the British Royal Navy decided to lease LR5, the commercial submersible built by Vickers Shipbuilding Limited[4], and adapt it to serve as the primary UK submarine rescue asset (Sussman, 2000b). The rescue vehicle subsequently underwent major upgrades to extend its lifespan and boost its capability[5].

With the growing numbers of submarines and nations operating them in the 1990s, the philosophy of collective rescue spread rapidly with the likes of the Royal Australian Navy initiating its own programme to custom-build a rescue system (Owen et al.).

RESCUE SYSTEMS IN THE 21ST CENTURY

The philosophy of submarine rescue had matured since the 1990s and the notion of having a holistic approach has been taken by countries that own and operate submarines. These countries often collaborate to offset the high cost of developing these submarine rescue capabilities.

Figure 2. DSRV-1 Mystic transported on a mother submarine (Source: Undersea Warfare – the official magazine of the US Submarine Force)

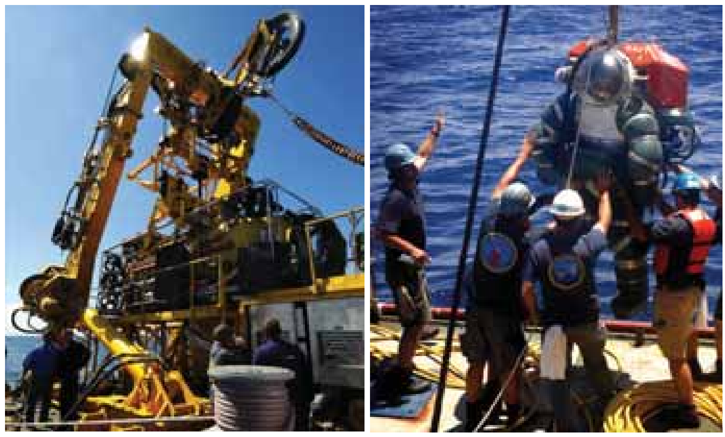

Figure 3. The SRDRS launched using its A-Frame (left) and the ADS (right)

US Navy

In November 2008, the Submarine Rescue Diving and Recompression System (SRDRS) shown in Figure 3 replaced the DSRV for submarine rescue capability. Implemented in a three-phased acquisition programme, the SRDRS comprises:

a. the Atmospheric Dive System (ADS) delivered in 2006 – The ADS was a one-man submarine with its own propulsion and side scan sonar that allows divers to inspect the DISSUB at depths of 2,000 feet (about 600 metres)

b. the unmanned Pressurised Rescue Module, Falcon, delivered in October 2008 – Falcon could operate at a maximum depth of 2,000 feet and has a rescue capacity for 16 personnel

c. a decompression system for hyperbaric treatment scheduled for delivery in late 2012

Operated as a flyaway concept, the design of the SRDRS allows it to be fitted on any Vessel of Opportunity (VOO) i.e. any available vessel, either military or commercial, that has the appropriate deck space and facilities to accommodate the rescue payload (GlobalSecurity.org).

Armed with an umbilical cable, Falcon has unlimited power supplied from the VOO and can be operated remotely via a command and control station located on that vessel. Hyperbaric transfer is possible with this new system, where rescued personnel can now be directly transported from the pressurised DISSUB to the decompression chambers without being subjected to atmospheric pressure. This minimises the chances of the rescued personnel suffering from decompression illness.

In emergency situations, the SRDRS rescue payload, which is currently maintained on the North Island in San Diego at all times, can be transported to the port nearest the DISSUB site to be embarked on the VOO. Such a 'plug-and-play' configuration is crucial in providing quick asset deployment across North America.

The US Navy has adopted the Government-Owned, Contractor-Operated (GOCO) approach for the SRDRS – a concept of commercialising the submarine rescue service that was pioneered by the UK. In the case of the US Navy, the responsibility to mobilise, operate and maintain the asset via a five-year contract period resides with commercial service provider, Phoenix International.

North Atlantic Treaty Organisation

In June 2004, the UK, France and Norway placed a contract with Rolls-Royce Power Engineering to develop a new system – the North Atlantic Treaty Organisation (NATO) Submarine Rescue System (NSRS). It was to replace the UK submarine rescue system (see Figure 4). The UK Defence Procurement Agency, on behalf of the three participants, manages this tri-nation project. Turkey, a participant during the project definition phase, remains an observer nation while she considers future financial involvement (International Submarine Escape and Rescue Liaison Office, 2008).

The NSRS Submarine Rescue Vehicle (SRV) entered service in end 2008. Unlike the unmanned and tethered Falcon, it is operated by two pilots in its command module, has a capacity for 14 rescuees, and can descend to a depth of 600 metres. To boost its endurance, Rolls-Royce incorporated its ZEBRA battery technology in the SRV. When compared to the lead-acid battery, the ZEBRA battery has almost doubled the submersible's energy density and endurance (Mortonson, 2007).

In the operations aspect, NATO has adopted a similar approach as the US Navy. In order to provide swift response to the call for rescue over a wide area, the NSRS SRV is currently based at HM Naval Base Clyde in Scotland and has been designed to operate off a VOO. For a service period of 10 years, NATO continued with the GOCO arrangement which the UK is familiar with.

Royal Swedish Navy

The Royal Swedish Navy started building its salvage and rescue capability in the 1930s when it acquired and refitted private salvage ships, as well as built rescue bells[6] to meet its purpose.

Figure 4. NSRS SRV launched from a support ship

To date, the Swedish Navy has its own Submarine Rescue Boat, URF. It is a free-swimming submersible that is able to rescue the whole DISSUB crew of 35 men in a single lift operation from depths of up to 700 metres. It is carried by its mother ship, HMS BELOS (see Figure 5), which is equipped with decompression chambers for 40 persons and is capable of hyperbaric transfer. HMS BELOS also has intervention systems such as a Remotely Operated Vehicle (ROV) Sea Owl and an ADS Mantis (Sorbet Royal, 2002).

Figure 5. BELOS III and URF
(Source of top image: U3 Veterans Crew Archives)

Figure 6. LR7 (Source: Getty Images Europe)

People's Liberation Army Navy

In 2008, the People's Liberation Army (PLA) Navy acquired a new submarine rescue vehicle, LR7, from Perry Slingsby Systems (see Figure 6). The 25-feet-long submersible can operate at depths of more than 300 metres and has a capacity for 18 rescuees. In addition, the PLA Navy also launched a new Type 926 Submarine Rescue Ship constructed by the Guangzhou Shipbuilding Company.

Republic of Korea Navy

The Republic of Korea Navy (ROKN) has acquired a new submarine rescue vehicle, ROKS DSRV II, which was designed and built by James Fisher Marine Services based on its Deep Search and Rescue (DSAR) 500 Class submarine rescue vehicle platform. ROKS DSRV II is able to operate up to 500 metres and can carry 16 personnel. Prior to this, the ROKN was operating the LR5K, a manned submersible that has a capacity for 10 personnel. The submersible is operated from a dedicated mother ship, Chung Hae Jin. A multi-purpose salvage and rescue vessel, Chung Hae Jin is also equipped with a ROV, a nine-man diving bell as well as a helipad for light helicopters. On-board recompression facilities are equipped with Transfer Under Pressure (TUP) capability (Lloyd's Register, 2009). Illustrations of the Korean system are shown in Figure 7.

Royal Australian Navy

From the extensive study commissioned by the Royal Australian Navy in 1992, the decision to build a new rescue system saw a tethered rescue capability in service in 1995. Named REMORA, this unmanned rescue module which weighs 16.5 tonnes is able to reach depths of 500 metres and rescue six crew members from the Collins-class submarines in a single trip.

Since June 2009, the Royal Australian Navy has leased the LR5 (see Figure 8), now owned by James Fisher Marine Services, to replace REMORA while it decides on acquiring a new submarine rescue system (Fish et al., 2009).

EQUIPPING SINGAPORE'S NAVY WITH SUBMARINE RESCUE CAPABILITY

The initial notion of equipping RSN to be capable of submarine rescue arose from the acquisition of Singapore's first submarine fleet, the Challenger-class submarines, from Sweden. In the 2000s, RSN envisaged the need to be self-sufficient in submarine rescue. As a result, the rescue capability comprising Submarine Rescue Payload and a dedicated Submarine Support and Rescue Vessel (SSRV)

Figure 7. LR5K (left), Chung Hae Jin (centre) and ROKS DSRV II (right)

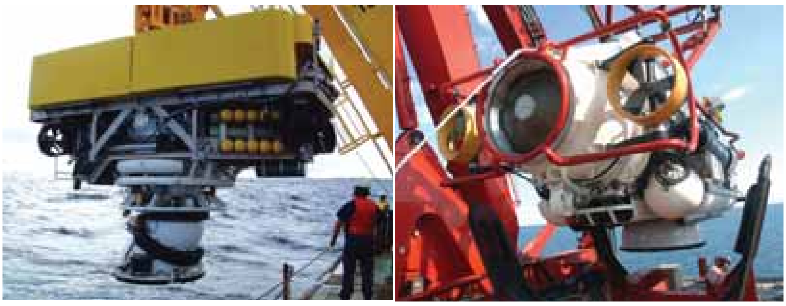

Figure 8. REMORA (left) and its replacement, LR5 (right)
(Source of left image: Royal Australian Navy)

was developed. The former, which comprised the SRV, Launch & Recovery System (LARS) and TUP System, would be on board at all times on the SSRV. When activated, the complete system would be deployed to the DISSUB site. The contract to develop this capability was awarded to First Response Marine Pte Ltd (FRM) in January 2007 via a 20-year Public–Private Partnership. FRM was to design, build, operate and maintain the Submarine Rescue System. The capability was delivered in 2009.

The SSRV, named Swift Rescue, carries the free-swimming submersible, SRV DSAR6 (see Figure 9). The design of the submersible is based on the DSAR 500 Class submarine rescue vehicle platform. Its dedicated SRV LARS is fitted at the aft of the SSRV main deck.

Figure 9. Swift Rescue and DSAR6

Swift Rescue and Rescue Payload

Swift Rescue is an 85-metre-long vessel built using the American Bureau of Shipping specifications and equipped with Dynamic Positioning-2 capability. It houses the rescue payload, certified by classification society Lloyd's Register, on its main deck where the main bulk of the rescue mission will be executed. Centred at the aft deck, the 30-tonne LARS is able to launch and recover the submersible up to Sea State 5 without the aid of swimmers. DSAR6, operated by two pilots and with a capacity for 17 personnel, is normally stowed in the sheltered hangar mid-ship on the main deck where the TUP system is installed. The submersible DSAR6 has an aft hatch to enable the pressurised transfer of personnel into the TUP system. A Deck Handling System is in place to move the submersible from its stowed position to under the LARS for deployment. Swift Rescue also houses the ROV system which can be deployed to survey or inspect the DISSUB site and assist to clear debris around the rescue hatch before deploying DSAR6.

The comprehensiveness of the rescue approach is evident, especially in the medical facilities that have been incorporated on board the Swift Rescue. Besides the TUP system, medical areas for various treatments (e.g. triage, sickbay and high dependency ward) have been identified. These are all located on the same deck as the TUP system to facilitate casualty movement and accountability. In addition, the ship has a helipad that is able to land a 12-tonne helicopter. This allows flexibility to bring more medical support from the mainland, and to transfer casualties to mainland hospitals when required.

The ship is also able to handle escape scenarios. The six-man Rigid Hull Inflatable Boat is equipped with a scoop to facilitate the recovery of personnel at sea. Upon recovery, they can either be transferred to Swift Rescue via its side jetty, or directly onto its main deck depending on the sea conditions.

Adherence to international standards, where possible, has been practised for the systems design evolution. For instance, all hatches and interfaces are standardised to STANAG 1297 rules. This allows interoperability with the systems and submarines of other nations that meet the same standards.

Sophisticated technology, equipment reliability and redundancy as well as system safety are critical for the success of rescue missions. Swift Rescue is equipped with the Integrated Navigation & Tracking System, which monitors the ROV, DSAR6 and DISSUB underwater during operation.

There are some significant improvements in the RSN rescue system that are different from many existing rescue systems. For instance, the lithium polymer battery, with its high energy density, is used on DSAR6 to enhance its performance. An air-conditioning system has been incorporated as part of the tropicalisation efforts – a first in SRV design – and this was made possible with the lithium polymer battery. In addition, it has a more capable trim system as well as an integrated skirt design complete with its own de-watering capability. Furthermore, the LARS is designed to deploy DSAR6 without assistance from swimmers, unlike most systems currently in use.

Another achievement is the creation of a removable raft on which DSAR6 and the TUP system are placed. This is a removable raft that allows the transfer of the rescue assets in a clean, single lift to the VOO, thus saving precious time during the preparation phase.

System safety was a critical concern during the design phase. The DSAR6 pressure hull has undergone hydrostatic tests before its assembly. Moreover, the lithium polymer battery system used in DSAR6 is certified by a classification society, which validated its safety features such as automatic cut-off for charging, and its visual and audio warning system for low battery status. These batteries are housed in separate pressure pods from the rescue chamber of the submersible – this adds an additional protective barrier to the crew on board the submersible and allows the pilots to jettison the battery pod if it is flooded.

Overall, the complete rescue system is one of the few in the world to incorporate various aspects of the rescue mission onto a single dedicated platform.

CHALLENGES AHEAD

To enhance security in submarine operations during peacetime, navies recognise that the submarine rescue capability is an important aspect to boost the psychological well-being of the submariners.

As efforts continue to break technology barriers to attain higher effectiveness and responsiveness in missions such as rescuing the DISSUB crew, there is much more that needs to be done to ensure rescue success. International cooperation and collaboration remain vital in complementing a nation's capability.

Inspired by the Kursk tragedy, the International Submarine Escape and Rescue Liaison Office (ISMERLO) was established in September 2004 under the auspices of NATO and the Submarine Escape and Rescue Working Group (SMERWG). This was a significant step towards global assistance in submarine search and rescue operations. With its web-based coordination tools, ISMERLO is able to facilitate rapid call-out for international rescue systems in the event of a submarine accident. The works of SMERWG and the importance of ISMERLO are gradually being recognised, especially in the international response and aid administered to the Russian AS-28 Priz submersible incident.

Through these lessons, nations are now practising their coordinated rescue efforts regularly. Multilateral search-and-rescue at-sea exercises such as Sorbet Royal[7] and Pacific Reach are held regularly with participation from NATO members and Asia-Pacific nations[8] respectively.

Development of more robust coordination, especially in establishing standardisation, will continue to be a challenge. Mutually accepted standardisation in terms of aspects such as submarine rescue seat design as well as communication script for the SRV and DISSUB is recognised to be crucial for submarine rescue. This allows consistency and compatibility to be established upfront among the different submarines and submarine rescue systems in the world, thus saving time during an emergency rescue. SMERWG, in particular, covers technical and procedural issues concerning all aspects of the subject with the aim of disseminating information and establishing mutually accepted standards for the design and operation of submarine escape and rescue systems.

CONCLUSION

The equipping of the RSN with a dedicated and comprehensive submarine rescue system has contributed to rescue capability in the region.

REFERENCES

Fish, Tim and Richard Scott. 2009. LR5 Sub Rescue System Moves Down Under. Jane's Information Group. http://www.janes.com/news/defence/jni/jni090617_1_n.shtml (accessed 24 August 2009)

GlobalSecurity.org. Deep Submergence Rescue Vehicle. http://www.globalsecurity.org/military/systems/ship/dsrv.htm (accessed 24 August 2009)

GlobalSecurity.org. Submarine Rescue Diving and Recompression System (SRDRS). http://www.globalsecurity.org/military/systems/ship/systems/srdrs.htm (accessed 24 August 2009)

Goldstein, Lyle and William Murray. 2008. International Submarine Rescue: A Constructive Role for China? Asia Policy, Number 5 (January). http://nbr.org/publications/asia_policy/Preview/AP5_SubRescue_preview.pdf (accessed 18 August 2009)

International Submarine Escape and Rescue Liaison Office. The NATO Submarine Rescue System. http://ismerlo.org/assets/NSRS/NSRS%20Factsheet%20Issue%204%201%20lo-res1%20_2_.pdf (accessed 24 August 2009)

Lloyd's Register. 2009. Lloyd's Register Helps South Korean Navy to Deep-dive Record. http://www.lr.org/news%5Fand%5Fevents/press%2Dreleases/index.aspx (accessed 24 August 2009)

Maas, Peter. 1999. The Terrible Hours: The Man Behind the Greatest Submarine Rescue in History. HarperCollins Publishers.

Mortonson, John. 2007. The Evolution of the Perry Slingsby Submarine Rescue Vehicles. Paper presented at Underwater Intervention, 30–31 January and 1 February, in New Orleans, Louisiana, USA.

Owen, Frank and Mike Poynter. Submarine Escape and Rescue – The Australian Solution. InDepth Project Management Pty Ltd. http://www.idpm.biz/downloads/submarine_escape.pdf (accessed 24 August 2009)

RHQ Eastland/HQ Navnorth. Sorbet Royal 2002: Submarine Rescue and Escape Exercise. Sweden – Units & Systems. www.sorbetroyal2002.celex.net/participants/sweden.htm (accessed 24 August 2009)

The Royal Navy Submarine Museum. Submarine Losses 1904 to Present Day. http://www.rnsubmus.co.uk/general/losses.htm (accessed 24 August 2009)

Sussman, Paul. 2000a. The Man Who Built the LR5. http://archives.cnn.com/2000/WORLD/europe/08/18/gordon.robertson/ (accessed 18 August 2009)

Sussman, Paul. 2000b. How Glider Enthusiast May Help Save Russian Sub. http://transcripts.cnn.com/2000/WORLD/europe/08/17/lr5.background/index.html (accessed 18 August 2009)

ENDNOTES

[1] This rescue was deemed "the greatest submarine rescue in history" by Peter Maas, author of The Terrible Hours which was based on the USS Squalus incident.

[2] Momsen's invention would not bear his name, despite his pioneering efforts and especially his great contribution to the success of the USS Squalus rescue. Lieutenant Commander Allan McCann was subsequently put in charge of the design revisions after the incident and the rescue chamber has since come to be known as the McCann Bell.

[3] The DSRV had a rescue capacity for 24 personnel and a maximum diving depth of 1,500 metres. The sister DSRV, Avalon, was launched in 1971.

[4] The submersible was named after the former chairman of Vickers Shipbuilding and Engineering Ltd, Sir Leonard Redshaw, who recognised the potential of using Glass Reinforced Polyester as the casing for deep-sea submersibles, instead of steel that was typically used then.

[5] The UK Ministry of Defence has since retired the LR5 from service with the commissioning of the NATO Submarine Rescue System.

[6] The Swedish bells were much influenced by the McCann Bell design.

[7] This was superseded by Exercise Bold Monarch in 2008.

[8] Singapore is one of the participating nations.

BIOGRAPHY

Dr Koh Hock Seng is Head Capability Development (Naval Systems) and a Senior Principal Engineer. He has extensive experience in the conceptualisation, planning, systems engineering and project management of large-scale systems such as the Republic of Singapore Navy (RSN) stealth frigates and Landing Ship Tanks. Hock Seng led the DSTA team in the systems development of the Floating Platform and the implementation of the Public-Private Partnership project for the submarine rescue service. He graduated with a Bachelor degree in Naval Architecture and went on to obtain his PhD in 1991 from the University of Hamburg, Germany. He currently serves in the Germanischer Lloyd's Technical Committee for Naval Ships. Hock Seng was awarded the Defence Technology Prize (1996, 2001 and 2007), the SAF Good Service Medal (2003) and the National Day Award (2001).

Chew Yixin is a Senior Engineer (Naval Systems) and is involved in the acquisition of submarine rescue services for the RSN. She works on the development of the submarine rescue system, with focus on the realisation of the Public–Private Partnership. Yixin was awarded the DSTA scholarship in 2001 and graduated with a Bachelor of Science in Aerospace Engineering, and a Bachelor of Liberal Arts and Science in Applied Mathematics from the University of Illinois, Urbana Champaign, USA in 2005.

Ng Xinyun is an Engineer (Naval Systems) and works on surface vessels platform acquisition and integration. She is involved in the development of the frigates and the submarine search and rescue vessel. Xinyun researched on the bulletproof properties of kevlar materials for her final year project and obtained her Bachelor degree in Mechanical Engineering (Honours) from the National University of Singapore in 2007.