海洋事務研究委員會專區
Specialized area of Marine Affairs Commission

導入水下科技應用提升海巡作業能量之推介

Recommendation on Introduction of Underwater Technology And Exaltation of Coast Guard Capacity

文｜邱逢琛
Article｜Qiu Feng-shen

壹、前言

隨著海洋委員會即將循著政府組織再造於民國101年啟動，而做為納編的主要執行機構的海岸巡防署，如能在傳統海面船艦作業能量的基礎上，導入水下科技系統和機具，培訓專業維運團隊，延伸建立水下作業能量，並與空中勤務協同建構海域三度空間的海巡作業能量，預期將能大幅提升我國海域執法、海事服務及海洋事務的執行效能，尤其在海域搜救方面。

貳、水下科技在海域搜尋之應用

水下載具技術和水中聲學是水下科技的兩大主幹，水下載具和聲納系統相互為用才得以建構出完整的水下作業能量。一般而言，水深超過五十公尺，潛水員的作業安全與效能會顯著受限，而且聲波是水中辨識和通訊的主要手段，陸上先進的電訊系統則難以直接派上用場，因此利用合適的水下載具配備適當的聲納和影像

Part I. Preface

Along with Oceanographic Commission started in 2012 after governments organizations were rebuilt, as main executive organ enrolled, Coast Guard Administration could introduce the systems and tools of underwater technology, train a professional team of maintenance and operation, extend and build up underwater working capacity, and establish coast guard capacity of three dimension by working with air service, on the base of the traditional offshore vessels' capacity, the executive efficiency of maritime law enforcement, marine service, marine affairs, and especially marine rescue shall be enhanced substantially.

Part II. Application of Underwater Technology for rescue on the sea

The main two parts of underwater technology is underwater vehicle and underwater acoustics. Underwater vehicles and sonar system reinforce each other to realize the perfect underwater working capacity. Generally speaking, the safety and efficiency of diver shall be limited obviously when depth is over 50 meters. Sound wave is major method to recognize

系統進入深海執行廣域或近場的調查(Survey)、搜尋(Search)、救援(Rescue)、回收(Recovery)等作業，乃成為必然的發展趨勢。台灣四面環海，緊鄰歐亞板塊陸棚邊緣，西部海域平均水深約七~八十公尺，而東部海底陡峭，離岸數公里已達數千公尺深的海域，因此海岸巡防業務主軸之一的搜救作業(Search and Rescue；SAR)往往必須面對大水深的挑戰。

台灣位居亞太交通樞紐，海空航線原本即已相當密集，而隨著兩岸經貿交流和人員往返的頻繁，民用航空器和客貨船舶跨越台灣水域的機會亦將日益增加，意外事故發生的風險也可能隨之提高。一般而言，海難或水域空難發生後第一時間啟動的搜尋和人命救援作業，通常是集中在水面作業，並以飛機或水面船舶執行為主。其後，或因保險理賠、或因防範未來，而有事故原因究明的需要，或是基於親屬對撈回罹難遺體的期盼，才會進行沈船或機骸，包括飛航紀錄器的搜尋和回收作業，此時就需要水下科技機具和專業團隊的投入。當然，也有因為水下作業自主能量的不足，或因機密原因，或因其他考量而放棄搜尋或打撈的案例。

and communicate underwater; actually the advanced telecommunication system in land is useless underwater. Therefore, the inevitable development trend is to equip the proper underwater vehicles with proper sonar and video systems for the near or further operations, such as survey, search, rescue and recovery. Taiwan is surrounded by sea, neighboring to the Eurasian Plate. The average depth of the western sea is 70-80 meters; the bottom of the eastern sea is so cliffy that the depth is thousands of meters where it is several kilometers faraway from the shore. So, the search and rescue (SAR) is one of main jobs of coast guard which faces a big challenge: deep water.

Taiwan is the transportation hub of Asia-Pacific, where the lines for vessels and planes have been dense; along with the development of the inter-coastal economy trade and personal exchange, more civil aircrafts and commercial vessels will trip across Taiwan territorial waters, the frequency of accidents will goes up. Generally-speaking, after shipwrecks or air accidents above the sea occur, search and life rescue shall be carried out first by the vessels and helicopters above the water. Later, for the need to check and survey the causes for insurance claim, future prevention, or for the deceased families' expectation for the bodies, the search and recovery for wreckage of vessels, airplanes and flight recorders shall be conducted. Now underwater technical tools and professional team are required. Of course, there are some cases that search and rescue was given up, for some reasons, such as lack in independent capacity, keeping secret and other considerations.

發生在去年6月1日，法航447班機從里約熱內盧飛往巴黎途中墜毀在大西洋造成216名乘客和12名機組人員身亡的飛航事故，由於黑盒子迄今仍未尋獲，而且欠缺目擊證言及雷達航跡資訊，因此事故原因的調查雖仍持續，但進展卻相當有限。罹難人員遺體和殘骸的搜尋回收作業已於當年6月27日叫停，黑盒子的搜尋作業也在當年8月20日中止。看似絕望了，但今年3月下旬發布的訊息顯示新的國際合作搜尋作業即將啟動，任務執行包含由美國伍茲霍爾海洋研究機構(Woods Hole Oceanographic Institution；WHOI)運用三艘可潛深6000公尺的自主式水下載具(Autonomous Underwater Vehicle; AUV) REMUS 6000，以側掃聲納(Side-Scan Sonar)進行地毯式掃描，測繪海床地形，以期比對出沉在深海的機骸，甚至於黑盒子的位置。若經由AUV REMUS 6000廣域掃描的聲學測繪影像能辨識出可疑的地點，則REMUS 6000將可配備高解析度攝影機進行近場光學影像攝錄作業。

同樣發生在去年7月7日，東加(Tonga)渡輪Princess Ashika的沉沒事故，雖有54人獲救，但也造成74人喪生。經由紐西蘭皇家海軍的協助，利用自主式水下載具REMUS 100進行搜尋，成功的定位了沈船，並使用遙控無人載具(Remotely Operated Vehicle; ROV)在近距離取得完整的光學影像，包括人員困在艙內的情形，公布的影像顯示沈船完整的正座在水深110公尺的海床上(參閱圖一)，而一般潛水員已經難以在這個深度進行有效率的水下作業了。

Last June 1st, Air France Flight 447 was a scheduled commercial flight from Rio de Janeiro to Paris that crashed into the Atlantic Ocean, killing all 216 passengers and 12 crew members. The investigation into the accident was severely hampered by the lack of any eyewitness accounts and radar tracks, as well as the airplane's black boxes, which had not been recovered from the ocean floor. On 27 June the search for bodies and debris was called off. The search for the black boxes was called off on August 20. This late March a new international cooperation organization announced to resume the search. Woods Hole Oceanographic Institution (WHOI) used three autonomous underwater Vehicles (AUV) of REMUS 6000 to carpet scan the ocean floor and survey and map the ocean floor terrain by side-scan sonar, hoping to find out debris and even the black box. If the possible sites can be recognized from optical images of wide-area channel scan through AUV REMUS 6000, REMUS 6000 can be equipped with HD camera for near-range acoustics video record.

Last 7 July, the Princess Ashika of Tonga sank, killing 74 persons although 54 persons rescued. With the help of New Zealand Royal Navy, autonomous underwater vehicle was put into use to search and position the sunk ferry successfully, and got the near-range completed optical image by Remotely Operated Vehicle (ROV), showing the detailed situation about the trapped persons and the ferry sitting upright on the ocean floor 110 meters deep underwater (See Picture 1.), otherwise, ordinary diver can not work efficiently at this depth.

▲ 圖一、渡輪Princess Ashika沉座海床影像(Source: Royal New Zealand Navy)
PIC 1. Image of the ferry Princess Ashika sunk(Source: Royal New Zealand Navy)

另外，發生在1999年11月15日，日本在種子島太空中心發射人造衛星失敗，H-II火箭墜入小笠原群島海域水深3000公尺處。經由日本海洋研究機構(Japan Marine Science & Technology Center; JAMSTEC)先後動用遙控無人載具ROV Kaiko、深拖聲納與攝影系統(Deep Tow Sonar & Camera)進行測繪搜尋，終於在當年12月24日發現主引擎，其後再動用ROV Dolphin-3K進行近場檢視，並在附近發現噴嘴裙(Nozzle Skirt)。最後，在不與民爭利的原則下，交由民間打撈公司利用ROV於2000年1月下旬完成回收，距失事日期前後僅費時約兩個月。

再回顧台灣近年發生的海域搜尋事件中，最重大者當屬發生在2002年5月25日的華航CI611班機澎湖空難事件225人罹難遺體和機骸的搜尋。當時在社會輿論高度關注之下，可說是集全國之力，動員包含交通部、漁業署、海巡署、海軍、飛安會、救難總隊、民間業者、美國專家以及國內海洋學界所有的海上作業能量，勉力以赴，執行遺體搜尋和機骸回收作業。惟事後的檢討，顯示日後除了海流、波浪等海域環境資訊預報精度有需要提升之外，側掃聲納等聲學測繪儀器的精度提升，以及ROV等機具的性能都有需要精進。

Additionally, on Nov. 15, 1999, Japan failed to launch a man-made satellite at Tanegashima Space Centre, and the Rocket H-II fell down into the water 3000 meters deep of Bonin Islands. Japan Marine Science & Technology Center (JAMSTEC) put ROV Kaiko and Deep Tow Sonar & Camera into use to survey and map for search, and then the main engine was found on 24 Dec., 1999; ROV Dolphin-3K followed to check and survey and find out Nozzle Skirt. At the end, in accordance with the principles to benefit the people, this task was moved to a folk company, and finished recovery in late Jan. 2000 which was about two months after accident.

For Taiwan, the most tragic air accident is that China Airlines CI611 accident occurred May 25, 2002, above Penghu, killing 225 persons. The public and media were highly concerned about the accident and all the possible forces were called to carry out search and recovery, such as Ministry Of Transportation, Fishing Administration, Coast Guard Administration, Navy, Air Safety Association, Rescue Corps, folk industry persons, American Experts, and all the marine working capacities. The late analysis tells us that the precision of ocean current and wave should be raised, and also the precision of Side-Scan Sonar and ROV, and some other equipments and tools.

參、水下科技系統和機具

自主式水下載具技術蓬勃發展迄今三十餘年，其技術已相當成熟，並早已達到實用階段而有市售成品或客製化產品可以取得。在軍事方面可應用於反潛(Anti-Submarine Warfare)、掃雷(Mine Countermeasures)、情蒐監視(Intelligence, Surveillance, and Reconnaissance)等；在商業方面可應用於海底管線路徑調查(Pipeline Route Survey)、海纜路徑調查(Cable Route Survey)、海纜佈放(Cable Deployment)、水文調查(Hydrographic Survey)、礦床調查(Mineral Field Survey)、油氣調查(Oil and Gas Survey)、海床測繪(Seabed Mapping)等；在科學研究方面可應用於地物調查(Geophysical Survey)、海洋學調查(Oceanographic Survey)等；而在海巡署業務相關的海域安全維護方面

Part III. Systems and Tools of Underwater Technology

The technology of AUV has been developed over 30 years and so mature already as it can be used. Finished products and customer design products are all available in the market. Militarily, it can be used for Anti-Submarine Warfare, Mine Countermeasures, Intelligence, Surveillance, and Reconnaissance; commercially, it can be used for Pipeline Route Survey, Cable Route Survey, Cable Deployment, Oil and Gas Survey and Seabed Mapping; scientifically, for Geophysical Survey and Oceanographic Survey; and for coast guard relevant security tasks, it can be used for Harbor and Port Security, Hull Inspection, Explosive Ordnance Disposal, Environmental Monitoring, Search and Recovery. AUV can be equipped with fore impact sonar, position and navigation system, acoustics/wireless/satellite communication system,

則可用於港埠維安(Harbor and Port Security)、船殼檢查(Hull Inspection)、爆裂物處理(Explosive Ordnance Disposal)、環境監測(Environmental Monitoring)、搜尋回收(Search and Recovery)等。自主式水下載具除了配備前視避碰聲納、定位導航系統、聲學/無線/衛星通訊系統、溫鹽深儀(Conductivity, Temperature, and Depth Sensor；CTD)之外，可搭載側掃聲納、多聲束聲納(Multi-beam Profiling Sonar)、海底層析聲納(Sub-Bottom Profiling Sonar)等聲學測繪系統執行海床的廣域測繪以協助搜尋定位，以及搭載照相/攝影/投光燈等光學影像系統執行目標物近場檢視。由於自主式水下載具可依規劃路徑和深度貼近海床執行聲學測繪，因此可以獲取遠高於船載聲學系統解析度的影像，有利於辨識，而且較不受海面風浪影響作業。

相對於AUV，遙控無人載具ROV的發展更早，而且因為受惠於海底石油產業的需求，技術發展更早趨於成熟。從潛深數百米、低階、價廉的遙控水下攝影載具，到潛深3,000米、有機械手臂、重裝的遙控水下作業載具都有市售成品或客製化產品可以取得。只是台灣周邊海域流強、浪高，一般低階的遙控水下攝影載具所配置的動力都難以維持載具正常運作，至於重裝的遙控水下作業載具則可以配置足夠的動力，在具備動態定位系統(Dynamic Positioning System; DPS)母船的支援下可以執行水下作業任務。然而，由於遙控載具需要人員介入操作，而且要與操船搭配，因此重裝的遙控水下作業載具的團隊成員需要精良的訓練，包含載具的維修保養。由於ROV與母船間有電力供應和資訊傳遞的臍帶相連，因此較難執行有效率的廣域搜尋，而較適合於目標物的近場檢視和操作。

此外，搭載聲納或攝影系統並藉助表面船舶動力拖曳的水下載具，在廣域聲學測繪或視訊搜尋作業上也早已是成熟而有效的機具。而搭載溫鹽深儀，利用浮力引擎(Buoyancy Engine)吸排水作動的自主式水下滑翔機(Autonomous Underwater Glider)在廣域水文資料的近即時蒐集作業上也已在近年趨於成熟而成為有效的機具。

Conductivity, Temperature, and Depth Sensor (CTD); and the acoustics surveying and mapping system, such as side-scan sonar, multi-beam profiling sonar and sub-bottom profiling sonar to help position by surveying and mapping wide-range ocean bed; and even picture/film/projector lighting and other optics image systems for near-range view. AUV can obtain higher identification images than vessels can which is easy to recognize, and avoid the influence from the ocean surface, because it can carry out acoustics surveying and mapping by the scheduled routine and depth.

Compared with AUV, ROV was developed and mature earlier, for it was needed and supported by marine oil industry. The products are available and customer designed at market, from basic film ROV of REMUS hundreds of meters and low price, to that of REMUS 3000 meters and machine robots. But the current around Taiwan sea area is strong, the former one can not work normally with slight weight, and the other one can be equipped with enough weight to work normally and carry out task with the help of the mother vessel equipped with dynamic positioning system (DPS). Because the ROV needs persons to join in operation and help of mother vessel, ROV requires a so well trained team that they are good at repairing and maintenance. ROV gets power supply and communication from the mother vessel, so it is suitable for near-range operation and view, instead of wide-range.

Moreover, the ROV carrying sonar or film system which gets power from the vessel on the surface is a mature and efficient tool for wide-range acoustics survey and map and video search. But the Autonomous Underwater Glider carrying CTD which is driven by buoyancy engine dewatering has been developed, mature and efficient day by day for wide-range water information real time collection.

肆、我國目前海域搜尋能量概述

我國除了現有的海研一、二、三號研究船、水試一號及達觀艦備有較完備的船載聲納系統可執行廣域聲學測繪搜尋之外，近期民間業者銓日儀公司於去年引進了275噸的寶拉麗絲號海測船，該船具備動態定位系統，船上配置有可潛深1,500公尺的ROV，其效能值得期待，而實際運作績效則有待後續關注。另外，已於前年(2008)七月正式成立的國家實驗研究院台灣海洋科技研究中心（簡稱海洋中心）正在國內中信造船廠新建一艘2,700噸的研究船，除了備有完備的船載聲納系統之外，該船具備動態定位系統，船上也將由海洋中心建置可潛深3,000公尺並有精密定位系統和高畫質攝影機的科學用重裝遙控水下作業載具。若一切順利進展，該船併同ROV預計將於2012年中開始營運。此外，海洋中心也已於今年引進了可潛深100公尺的小型自主式水下載具AUV Iver2(參閱圖二)，以及可潛深200公尺的自主式水下滑翔機Slocum Glider(參閱圖三)，並已著手進行運作測試，預期將能逐步建立營運自主式水下載具的能量。此外，海洋中心正在建置中的環島高頻雷達CODAR測流系統，預計在2011年完成，屆時將能提供台灣週邊海域表面海流即時流速分佈圖譜，成為提供海域搜尋關鍵資訊的一大利器。

Part IV. Summary of Taiwan Current Capacity of Marine Search

In Taiwan, Research Vessel No. 1, No. 2, No. 3, Marine Experiment Vessel and Daguan Naval Vessel equipped with shipboard sonar system can carry out wide-range acoustics survey and map and search, and so can the marine survey vessel "Borulice" with displacement tonnage of 275 tons, recently introduced by a folk company called Quan Ri Yi which is equipped with dynamic position system, ROV of REMUS 1,500 meters; her capacity is worth waiting for, and her practical efficiency of operation shall be concerned in future. Additionally, a research vessel with displacement tonnage of 2,700 tons has been building at Jong Shyn Shipbuilding Yard for the Taiwan Marine S & T Research Center (Marine Centre) under National Experiment Research Institute officially founded in July, 2008, and this vessel shall be equipped with shipboard sonar system, dynamic position system and a weight ROV of REMUS 3,000 with precise position system and HD camera, which is built by Marine Center, if smoothly, the vessel with the ROV shall be put into use in 2012. Moreover, Marine Center introduce an AUV called Iver 2 of REMUS 100(see picture 2) and an autonomous underwater glider, called Slocum Glider of REMUS 200 (See Picture 3), and have started to test operation, with expectation to gradually develop a capacity to operate AUV. Marine Centre is building a high frequency radar "CODAR", expected to complete in 2011, and then it can provide real-time speed map of sea current around Taiwan, and it will be a powerful tool to provide key information for marine search.

▲ 圖二、測試中的AUV Iver2 (影像來源:台灣海洋科技研究中心)
PIC 2. AUV Iver 2 in test (Source: Taiwan Marine S & T Research Center)

▲ 圖三、測試中的Slocum Glider (影像來源:台灣海洋科技研究中心)
PIC 3. Slocum Glider in test (Source: Taiwan Marine S & T Research Center)

伍、結語

海洋科學知識的探究是推動海洋科技發展的主要動力之一，許多先進的水下科技系統或機具也因此在海洋科技研究機構發展、建置和運用，並在必要時提供做為緊急應變的主要依靠。然而這畢竟不應該是常態，而且隨著水下科技發展的日新月異，許多成熟而實用的系統或機具也從海洋科技研究機構釋出，移轉到市面上公開販售或接受客製化訂製。海洋中心既已成立，未來必將擔負發展、建置和營運先進的海洋及水下科技系統和機具的任務，而海域執法、海事服務及海洋事務的實際執行，包括海域搜救仍需仰賴站在第一線的海巡作業能量。

最後，期許擔負我國海域執法維安任務的海岸巡防署和海洋科技研究機構之間密切合作，加強導入水下科技系統和機具，培訓專業維運團隊，提升水下作業能量，並與空中勤務協同建構海域三度空間的海巡作業能量，大幅提升我國海域執法、海事服務及海洋事務的執行效能，尤其在海域搜救方面。

（本文作者現職為國立臺灣大學工程科學及海洋工程學系教授）

Part V. Conclusion

Exploration of marine science is one of the most important driving forces to promote marine science and technology development. Many underwater S & T systems and tools are designed, developed, built and operated in marine S & T research organs; if needed, they are provided out as emergency tools. But this situation should not be a normal state, because today the science and technology changes and develops rapidly, some of these have come out of the research organs to the market for public sale. Marine Center must take the task to develop, build and operate the advanced marine and underwater S & T systems and tools. Maritime law enforcement, marine service, marine affairs and marine search and rescue all depend on the capacity of coast guard.

Finally, hope a close cooperation between CGA and marine S & T research organs, introduce of underwater S & T systems and tools, train a professional team of maintenance and operation, raise underwater working capacity, and build up coast guard capacity of three dimension by working with air service; the executive capacity of maritime law enforcement, marine service, marine affairs, and especially marine rescue shall be enhanced substantially.

(The auther currently works as a researcher at the Professor of Engineering Science & Ocean Engineering Department, National Taiwan Uniwersity Member of Marine Affair Research Council)