出國報告（出國類別：其他）

參加第 44 屆廢棄物管理研討會出國報告

服務機關：核能研究所
姓名職稱：陳永枝　助理研究員
派赴國家：美國
出國期間：107 年 3 月 16 日~107 年 3 月 25 日
報告日期：107 年 4 月 24 日

參加第 44 屆廢棄物管理研討會出國報告

陳永枝

摘要

核能研究所陳永枝博士奉派出國公差，自 107 年 3 月 16 日至 25 日共計 10 天，參加於美國亞歷桑納州鳳凰城市舉行之第 44 屆廢棄物管理國際研討會(Waste Management Symposium, WM 2018)，並於該會議上發表論文—「Preliminary Planning of Radwaste Management for the Decommissioning of Chinshan NPP in Taiwan」。

廢棄物管理研討會目的主要促進各國於廢棄物管理各方面的交流與互動，藉由與核能先進國家如法國、美國、韓國、及日本等專家學者進行討論與交流，蒐集有關各國放射性廢棄物處理現況與管理技術，提升本所對於廢棄物管理的觀念及技術。這次會議分成 140 場次進行，共計發表 450 篇論文，主題包括：低/中放射性廢棄物管理、用過核子燃料與高放射性廢棄物管理、設施除污與除役、環境復育、環境管理及民眾參與等相關議題，議題範圍廣泛包含放射性廢棄物管理相關議題，與會人員參與討論及技術交流。

關鍵字:

放射性廢棄物管理、除污、除役

一、目的

廢棄物管理研討會(Waste Management Symposium, WM)為國際上廢棄物管理最重要的會議之一，歷來都在美國亞歷桑納州鳳凰城舉行，本所每年均派員參加，本次第 44 屆大會共有來自全球眾多國家的專家學者與會。WM 探討主題範圍廣泛，分為下列九大議題：跨部門的政策和整合、高階放射性廢棄物(HLW)及用過核子燃料(SNF/UNF)、低階放射性廢棄物(LLW)及中階放射性廢棄物(ILW)、核能電廠廢棄物管理及用過核子燃料的貯存、包裝與運輸、除污與除役、環境復育、溝通與技術和管理與影響的訓練及跨領域等。

作者目前參加核一廠及核二廠除役計畫工作，負責放射性廢棄物管理技術開發，此次奉派參加會議，並發表核一廠除役工作先期規劃關於放射性廢棄物管理之研發成果論文，展現我國在相關領域的研究能量，同時藉由藉由國際會議平台，與各國相關領域之研究單位專家學者討論，強化國際研發人脈，嘗試建立合作管道，加速本身技術提升進程；收集有關於放射性廢棄物管理之最新資訊及技術發展，進而瞭解國際上研發現況與市場趨勢，作為我國未來放射性廢棄物管理技術發展方向之參考。

二、過程

(一)概要說明

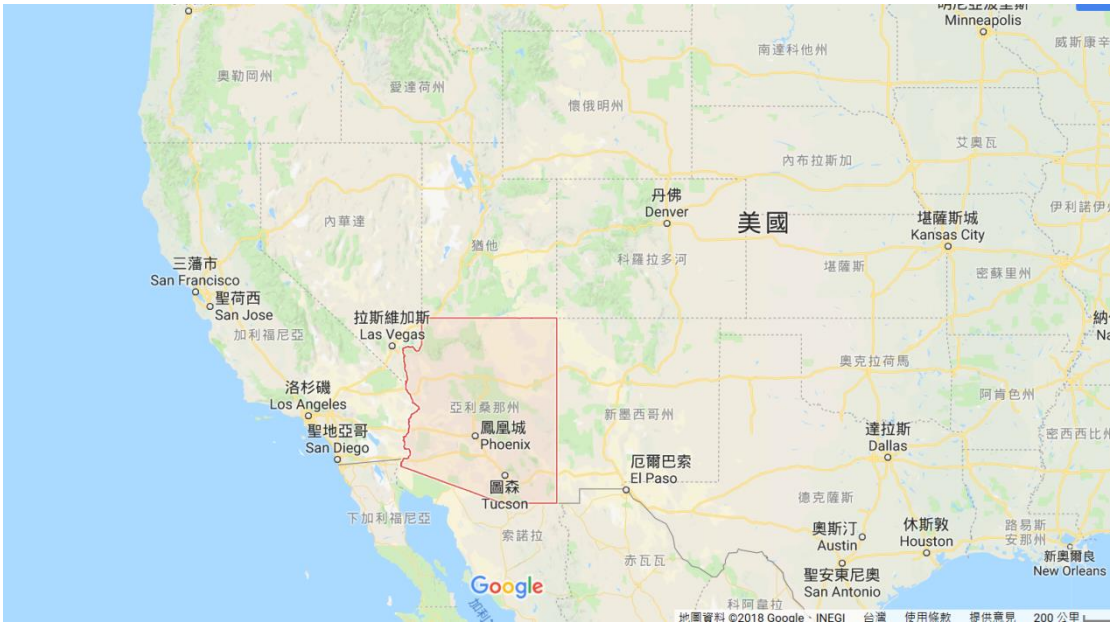


圖 1. 亞利桑那州於美國相對地理位置

圖 2. WM 會議地點-美國鳳凰城 Convention Center

第 44 屆廢棄物管理研討會(WM 2018)於 2018 年 3 月 17~22 日於美國亞利桑那州鳳凰城 Convention Center 舉行，相關地理位置如圖 1 與圖 2 所示，為目前國際上放射性廢棄物管理領域重要會議之一。本屆大會約有 450 篇論文發表，以及學生論文海報競賽，分成 140 場次進行討論，參加人數約 2000 人，大會寄發大會邀請函，如附錄一。

核能研究所在本屆會議共發表口頭論文 2 篇及海報論文 1 篇，論文題目分別為「Preliminary Planning of Radwaste Management for the Decommissioning of Chinshan NPP in Taiwan」、「Adsorptive Removal of Cs-137 and Sr-90 from Water in the Spent Fuel Pool of Taiwan Research Reactor」及「Packing Optimization for Dismantled Parts of Nuclear Facilities」。

(二)行程說明

本次公差共計 10 天，行程如表 1 所示，3 月 16 日啟程經由美國舊金山轉機至鳳凰城， 3 月 17~22 日參加會議與發表，3 月 23~25 日回程。

表 1 公差行程與主要活動說明

日期	地點	主要活動說明
3 月 16 日	台灣桃園-美國鳳凰城	啟程與轉機
3 月 17 日	美國鳳凰城	報到
3 月 18~22 日	美國鳳凰城	參加專題演講、發表論文及參觀論文海報暨儀器展
3 月 23~25 日	美國鳳凰城-台灣桃園	

3 月 16 日早上 10:30 由台灣桃園國際機場搭乘長榮航空 BR8 班機起飛前往美國加利福尼亞州舊金山，過程為先於美國時間早上 06:30 抵達舊金山國際機場並停留約 5 小時，轉機飛往鳳凰城天港際機場，於同日美國時間 13:20 抵達，辦理完成出關手續後，轉搭計程車前往旅館。

圖 3. 台灣桃園國際機場搭乘長榮航空班機前往美國

會議議程與每日討論主題內容請參見附錄二。以下簡略說明研討會九項議題：

Track 1: Crosscutting Policies and Programs (CPP)

Track 2: High-Level Radioactive Wastes, Spent Nuclear Fuel/Used Nuclear Fuel (SNF/UNF) and Long-Lived Alpha/Transuranic Radioactive Waste (TRU)

Track 3: Low-Level Waste(LLW), Intermediate Level Waste(ILW),Very Low-Level Waste(VLLW), Mixed Waste(MW), Byproduct Material, TENORM, NORM Residues, Enriched and Depleted Uranium (DU)

Track 4: Nuclear Power Plant (NPP)Waste & On-Site SNF/UNF Storage

Track 5: Packaging and Transportation

Track 6: Decontamination & Decommissioning (D&D)

Track 7: Environmental Remediation (ER)

Track 8: Communications, Education and Training of Technical and Management Issues & Impacts (CE&T)

Track 9: Special Topics Including Multi-Track Cross Cutting Technology Topics (ST)

議題一: 跨部門的政策和整合

包含整體跨領域政策和重大計畫，非屬跨領域者將歸類置個別專門議題（例如高階放射性廢棄物，用過核子燃料，低階放射性廢棄物等）或處理程序（例如除役與除污等）的整合。特別鼓勵探討從國家、跨國和國際合作層面來探討廢棄物管理政策，主要包括跨領域法規、承包、法律、許可及相關合法事宜、規範和標準的建立及其他高層次涉及多樣廢棄物類型/策略交叉等議題。

議題二：高階放射性廢棄物(HLW)、用過核子燃料(SNF/UNF)、長半衰期阿伐(Alpha)核種與超鈾廢棄物(TRU)處理

主要討論有關長半衰期阿伐核種與超鈾廢棄物TRU、核電廠用過核子燃料SNF及高階放射性廢棄物等的相關技術開發與應用、回收/再處理策略與技術等處理和處置。定期性進度更新與其中關於重疊的問題，包括SNF和高放廢物中期和最終處置策略、貯存廢棄物環境許可證書及監測議題，廢棄物處理的替代程序、廢棄物的形式、深層處置和操作設施發展及風險評估，與直接相關的法規和標準的影響。

議題三：低階放射性廢棄物(LLW)、中階放射性廢棄物(ILW)、混合形式廢棄物(MW)產物質、技術操作產生的天然放射性物質、殘留的天然放射性物質(NORM)與乏鈾(DU)

對處理到處置所需的操作技術、技術開發、小量處理示範和部署安排，重疊議題包含廢棄物如何最小化、廢棄物特性分析、排放水監測、廢棄物形式和設施營運評核、法規和標準、而各類設施型態從醫院、加速反應器、研究反應器、政府設施，處置設施等。本議題也包含了鈾或釷礦石廢棄物管理以及“從超 C 類(GTCC)至低放廢棄物”，二次廢棄物、技術操作產生的天然放射性物質、殘留的天然放射性物質(NORM)。

議題四：核能電廠廢棄物管理及用過核子燃料的貯存

涵蓋核電廠營運時產生的廢棄物特性分析、如何最小化、處理、包裝與管理，及核電廠運轉中所產生廢棄物及用過核子燃料的貯存與管理

議題五：包裝與運輸

主要是關於放射性物質的安全、保全、商業的包裝和運輸問題。放射性物質包括了 HLW、TRU、LLW、ILW 和 MW；還包括未照射與照射的核子燃料，受污染的介質及雜項，同位素和射源，六氟化鈾等。小組討論包括國際正規活動、議題和倡議，包裝發展及相關議題，物流和運輸業務，包括大型項目從除役、整合計畫和行程表，針對大型航運活動的議題與情形，與利益相關者和公眾互動議題。

議題六：除污與除役(D&D)

探討有關停役核電廠與反應器的除役事宜，或執照即將中止的計畫與如何成為綠地，包含廠址調查、除污、貯存、拆解、拆除、廢棄物處理、最終調查，以及相關新技術的發展為政府和商業核電和非核電設施。包括世界各國的除役技術和相關策略，以及監管方面的問題。

議題七：環境復育(EM)

主題包括了污染場址的評估、清理和封閉，探討如何恢復和保護人們健康和環境，透過調查、清理、封閉、長時間場址管理。著重在是地上和地下補救措施和清理活動，包括現場檢查、鑑定和評價、採樣和分析、符合法規的監測、解決監管問題影響清理、含水層和土壤修復、從管理的清掃活動產生的廢物、修復的設計和實施、透過技術或程序改善加速清理、封閉、永續的綠化修復和傳統管理/長期監控。

議題八：溝通、教育與技術和管理與影響的訓練

此議題包含 5 大主題，其中包括在廢棄物管理從業人員、政策制定者、執行者間獲得多元觀點，以進行有效溝通；提高公眾參與程度，以確保決策代表性；國際間創新想法分享；在資訊溝通與知識管理的新亮點方法及改善工作環境等。

議題九：特別主題和跨多個議題技術討論

此議題包含美國和非美國在國際安全、保安和安全導則和美國國土和國際安全問題。它也包括技術議題橫跨多個主題－有關不知名的廢棄物源和密封源，綜合風險管理、模示建立、合規行動，規範和標準的建立，自然資源損害評估（NRDA），技術部署，儀器儀表，過濾，高級技術，極端環境下的操作技術，技術驅動程序的影響和驅動程序，與涉及多個廢料形式或放射性物質等技術交叉問題。

大會開幕及演講

圖 4. 大會開幕式

大會主席 Jim Gallagher 於開幕致詞演講中提到: 「很歡迎大家參加第 44 屆廢棄物管理研討會，這會議是國際上最重要的放射性物質管理的會議，今年很驕傲地邀請來自 33 個國家 2000 多名代表參加本研討會」。

隨即展開今年度的大會演講，第一位是田納西州第 3 區眾議員 Chuck Fleischmann，他是眾議院撥款委員會的一員，在這委員會下，還有能源和水資源發展、國土保安、勞工、健康及教育等次委員會。他於演講中提到，目前清理計畫面臨的重大挑戰之一是確保那些已經在做的工作有足夠人才繼續執行下去。因為半數清理人力在兩年內即將退休，且社會對核能的興趣已開始減弱。他呼籲與會參加者「走出去，告訴年輕人核電、核能及核廢料清理的重要性」。進一步地，他也強調人員訓練的重要，「當美國核能產業向前進時，清理工作很重要，但也要確保我們有一批年輕的核能工程師來支撐」。

第二位大會演講者為 Veolia Nuclear Solution Federal Services 公司的總裁兼執行長 Billy Morrison。他說: 「雖然在美國，已經完成很多廢棄物場址的清理工作，但是很多持續性的威脅仍舊存在。我們面臨技術挑戰、財政挑戰、風險挑戰以及那些因設施老化而造成的挑戰，我們需要健全且長期的方向去解決它---一個專注於效率優先的計劃」。且他提到美國能源部應該走出來，與利益相關者及周遭社區人士一起努力，尋求他們的幫助、建議或想法，「不要被過去所侷限，如果我們要有意義地修訂，我們需要新思維及變得更敏捷」。

第三位大會演講者 Jim Colgary，他是美國能源部(DOE)能源副秘書長的幕僚長，他說: 「目前政府承諾進行必要的改變，以便部會可以成功執行業務。我們正在進行於公私合作關係、法規改革及增強自身能力，以將事情完成」。以及政府正持續往前發展一全面性包括太陽能、煤炭、石油及核能的能源計畫，也致力於再生能源的研究，但是他提到仍需要較佳的儲存選項，包括擴展電池、水、壓縮空氣和其他創新想法等研究領域，以符合我們未來的需求。

另外，還有令人印象深刻的儀器設備展覽，展覽主題包括今年的主題展「機器人大展」、核能及工業應用機器人、遠端遙控及其他新興技術等，聚焦於最近的發展與未來的規畫。並且由任職於美國太空總署(NASA)軟體、機器人及模擬部門主管 Ambrose 博士於 3/19 中午針對機器人應用進行大會演講，開啟機器人

大展的序幕，如圖 5 所示。Ambrose 博士提到 NASA 正專注於發展可穿戴式自動化裝置，不是為了取代工作者，而是為了協助工作者。他說:「雖然 NASA 的焦點是放在改善太空人的太空衣，但這些進展也可以幫助人們做其他各式的工作，特別是針對那些傷者或失能者。人類將可遇見機器人變得更聰明，材質變得更輕，以及像是電池變得更耐用等新科技。其中穿戴式自動化裝置也已經用於安全頭盔、面罩甚至是虛擬實境遊戲中。下一個應用產品可能是甚麼? 或許是可提供較強握力的手套、對受傷戰士物理治療用的機械手臂裝置和具輔助行走的義肢。而虛擬實境也已經幫助人們變得更有創造力、減少犯錯，且此科技也逐漸用在私領域方面，像是運動方面，而這回饋也有助於 NASA 的技術改進」。除此之外，尚有非常多篇報告是有關於自動化應用的，且儀器設備展上也有不少實體展示，如圖 6 所示。附錄三列出六篇美國 DOE 於大會會場展示的海報，皆是有關機器自動化的應用。

圖 5. Ambrose 博士的機器人應用演講

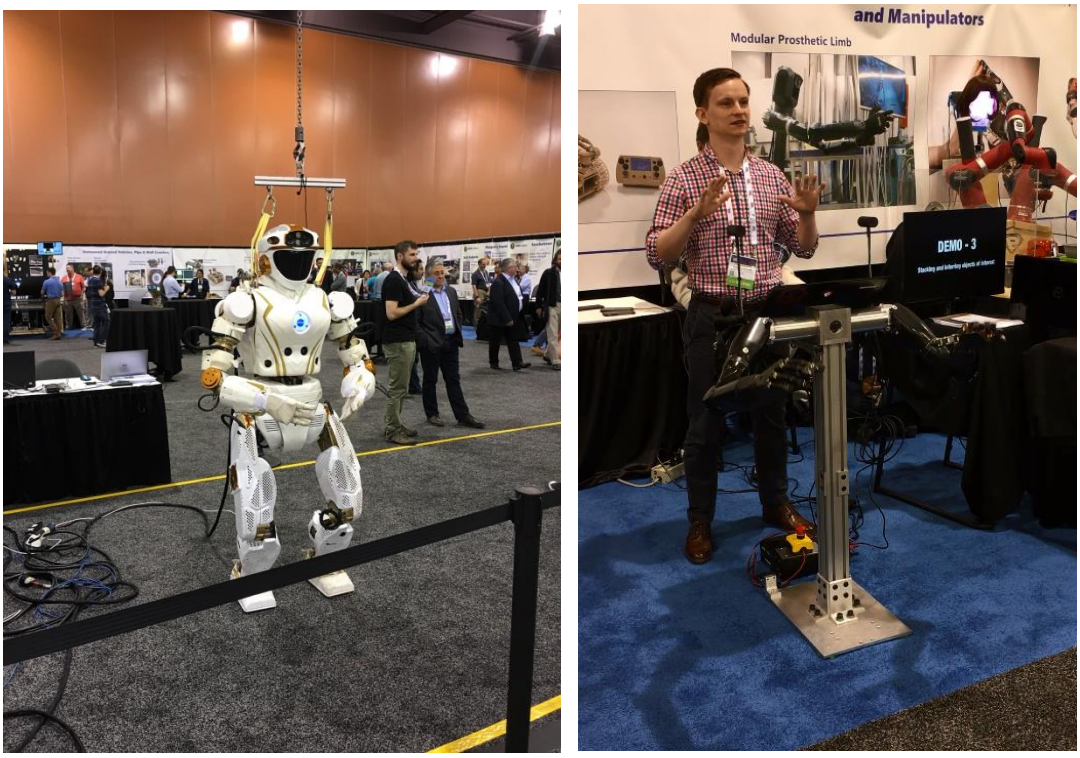


圖 6. 儀器展上展示的機器人(左)與遠端遙控機器手(右)

在第 79 場次的專家小組會議中，討論到未來清理工作中，將有很多都是需要自動化機器去完成。但是昂貴的成本仍然是阻礙技術前進的一大障礙。其他挑戰包括自動化機械是否適合於高輻射區域運作和水中環境操作等。另外、工作人員接受程度、訓練和效率等也都是要考量的主要因素。

發表論文

接著展開各場次論文發表及小組討論，由作者發表之口頭論文報告就在第一天下午，而依據大會慣例，當天的論文發表者必須參加早餐會報，由資深專家學者擔任共同主持人，主持論文發表會及掌握進度。因此，一早 7:00 就進會場，作者是於第 30 場次發表論文，共同主持人為美國 NRC 的資深顧問 Rateb (Boby) Abu-Eid 博士及 Cyclife 公司的 Maria Lindberg 博士，主要說明下午簡報注意事項。作者發表的論文題目為「Preliminary Planning of Radwaste Management for the Decommissioning of Chinshan NPP in Taiwan」，主要內容為說明台灣核一廠未來除役時廢棄物管理的初步規劃，提出廢棄物管理心智圖，系統性進行廢棄物盤點、

減量、除污與預估所需人力等，摘要詳見附錄四。口頭發表時間 25 分鐘，見圖 7，結束後專家提問是否有外釋經驗及如何確認偵檢儀器正常。也有很多外國廠商會議後前來詢問，希望能提供相關資料，認為台灣第一座核電廠要除役，商機很大，有興趣想多了解。至於其他國家的除役工作，歐美有些國家已開始核電廠及核設施除役清理工作，東歐與南韓尚處於除役規劃階段，進度上有明顯的差異。

圖 7. 發表口頭論文

有興趣的議題

此次議題場次非常多，僅摘錄一些有興趣的題材說明。

首先是政策面修訂討論，在場次 21，討論有關美國低放射性廢棄物的新興管理議題，法規面修訂，包括進行中的第 61 條修訂案 (Part 61 Licensing Requirements for Land Disposal of Radioactive Waste)、超 C 類管理基準、替代性的處置要求準則修訂、低微放射性廢棄物研究及反應器除役法規制定等。會中提到，於 2017 年 9 月委員會即要求 NRC 進行第 61 條的修訂，包括允許新的必要

條件逐一申請、1000 年法規規定期間的復育、安全範例定義的澄清、縮小深度防禦的考量和成本與利益的被告知等，並希望在今年夏天完成修訂。另外，值得一提的是，美國已不僅於專注於放射性廢棄物的管理，核電廠除役廢棄物中還有很多非放射性污染物，也開始被要求事先規劃處理時程。

有關除役階段的除污技術，日本 IHI 公司發表的遠端遙控雷射除污系統。雷射清潔技術其實很早就廣泛應用於工業界，像是汽車、航太及半導體業。而應用在放射性廢棄物的切割及除污約在 10 年前開始，如圖 8 所示。主要優點為產生很少的二次廢棄物以及容易進行遠端遙控，這對於高輻射區域的除污顯得特別有利基。IHI 公司使用的雷射功率約 75 w，在重複約 10 次後，其除污因子(DF)可達 250-300。除污前後的比較可見圖 9。本次會議發表即是根據之前技術，搭上自動化，應用於遠端遙控上，如圖 10 所示，據報告顯示，2017 年 12 月會進行遠端雷射除污測試，惟目前尚未見報測試報告，僅提到將持續改進其系統。至於其除污過程所產生廢棄物，係由側邊風管抽至絕對過濾器處理，如圖 11 所示。初步看來，雷射除污對處理平面型物件較佳，其他形狀物件表面使用上會受限制。

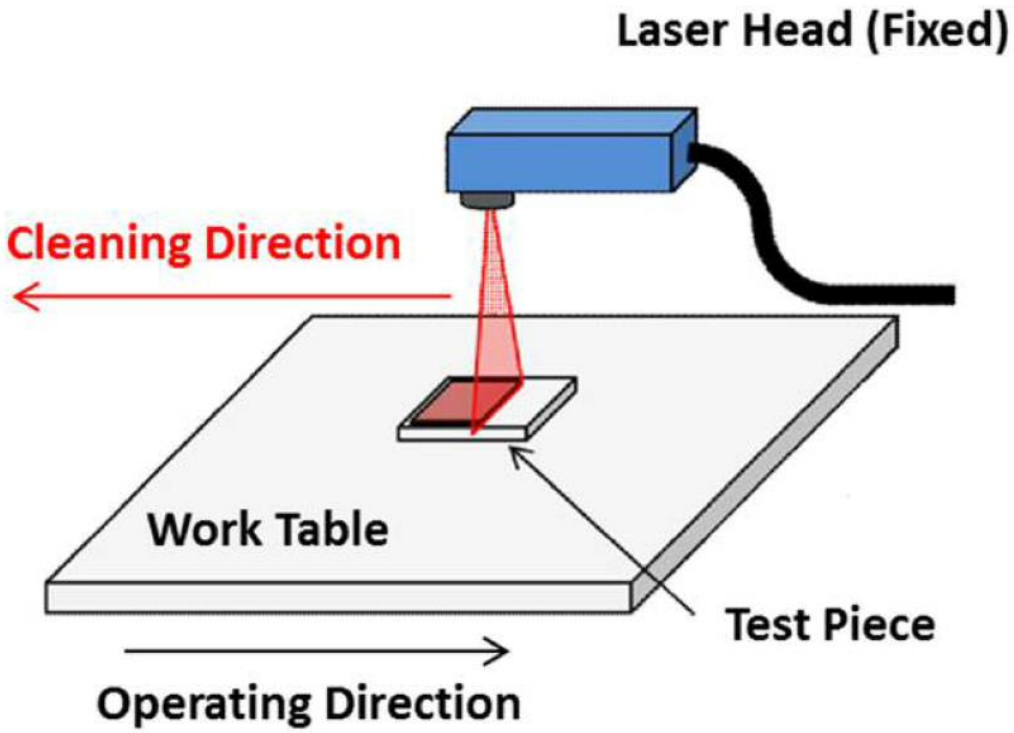
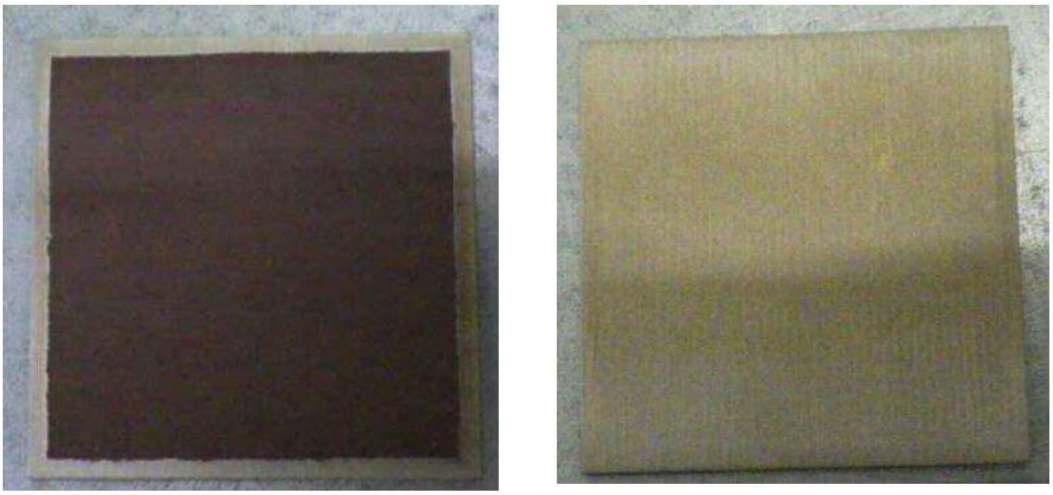


圖 8. 雷射除污概念



(Left: Before laser cleaning, Right: After laser ablation)

圖 9. 雷射除污前後比較

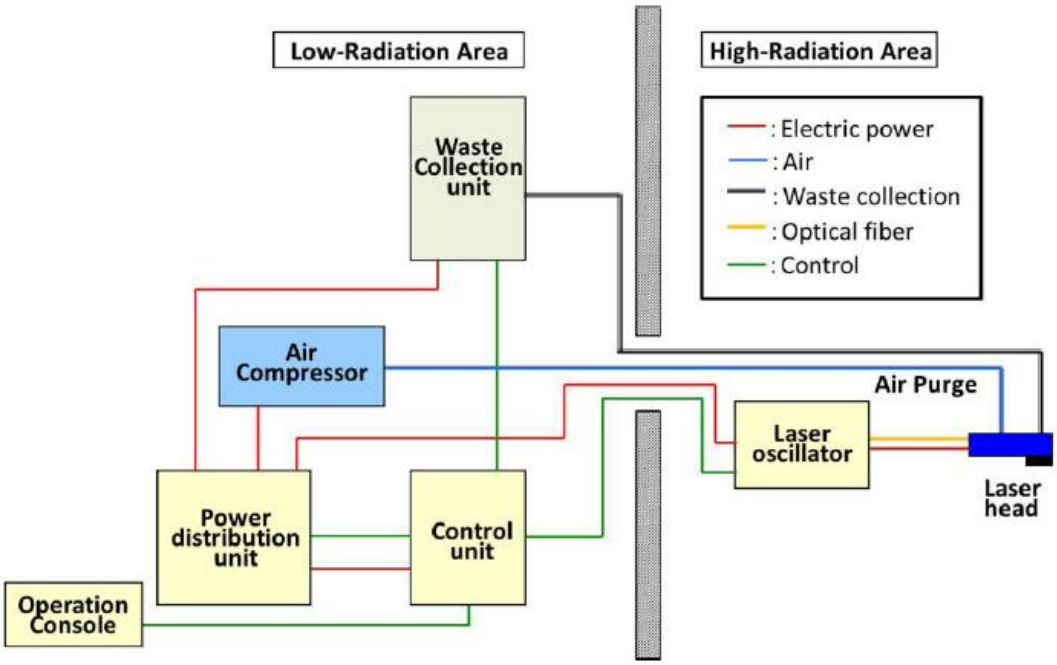


圖 10. 遠端遙控雷射除污

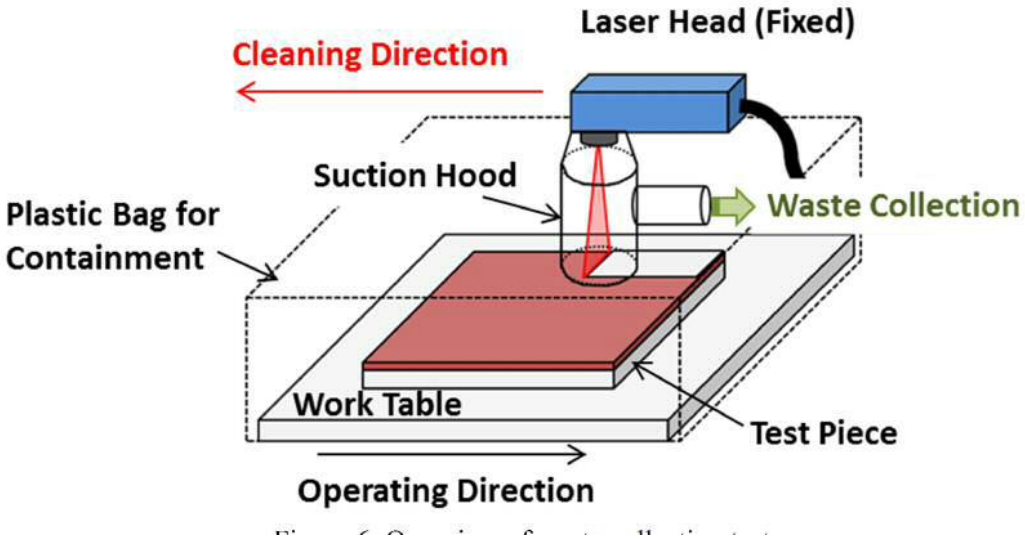


圖 11. 二次廢棄物收集

法國原子能署(Commissariat a I'Energie Atomique, CEA) 核能部門專案經理 Christophe Girold 發表創新的高溫程序，以處理除役階段廢棄物和既有廢棄物。他主要提到三個專案: PIVIC、DEM& MELT 及 MILOR，宣稱後兩項專案即將商業化，第一個則還在先導型階段。所謂高溫處理，所使用的技術就是電漿技術，採用的電漿形式與功率不同，以下分別說明。PIVIV 專案(Process of Incineration Vitrification in Can)，如圖 12，是指桶裝放射性廢棄物以高溫電漿進行焚化及玻璃化的處理程序。主要用來處理混合型(有機/無機/金屬)含阿伐(alpha)廢棄物，於其境內至 2015 年約有 10,000 桶，每年產生 800 桶。這系統採用電漿火炬為熱源提供者，型態為純氧火炬，功率約 300 kW，壽命約 100 小時。根據其發展歷程表，2012 年為第一期研究起始年，大約是桌上型規模，第二期驗證其概念，第三期為先導型，主要是整合及調校參數，今年是屬於第三期，看起來仍屬開發階段，尚未成熟。

第二個專案是 DEM&MELT，也是將廢棄物玻璃化的系統，是將設備組件置於 20 呎貨櫃中的小系統，參考圖 13，主要核心是桶內熔融鍋，前端有進料槽，後端則是洗滌塔、冷凝器等廢氣防制設備，然後可於除役階段現場進行處理。主

要用來處理高活度的難溶廢棄物，像是老舊桶槽或蒸發器的污泥或沉積物。

第三個專案則是 MILOR，是用電漿火炬來處理放射性含鹵素有機液體，如圖14。採用的電漿為低功率射頻電漿(4-5 kW，> 1MHz)，待處理液體直接導入電漿火炬反應槽，藉由電漿產生的氫氧自由基去破壞碳-鹵鍵，達到分解效果(三氯甲烷去除率 99%以上)。另一個應用領域為油脂、閃爍液與含磷溶劑等，用的是直流電弧氧氣電漿(30kW)，以處理磷酸三丁脂(TBP)及十二烷為例，分解效率在99.7~99.9%之間。

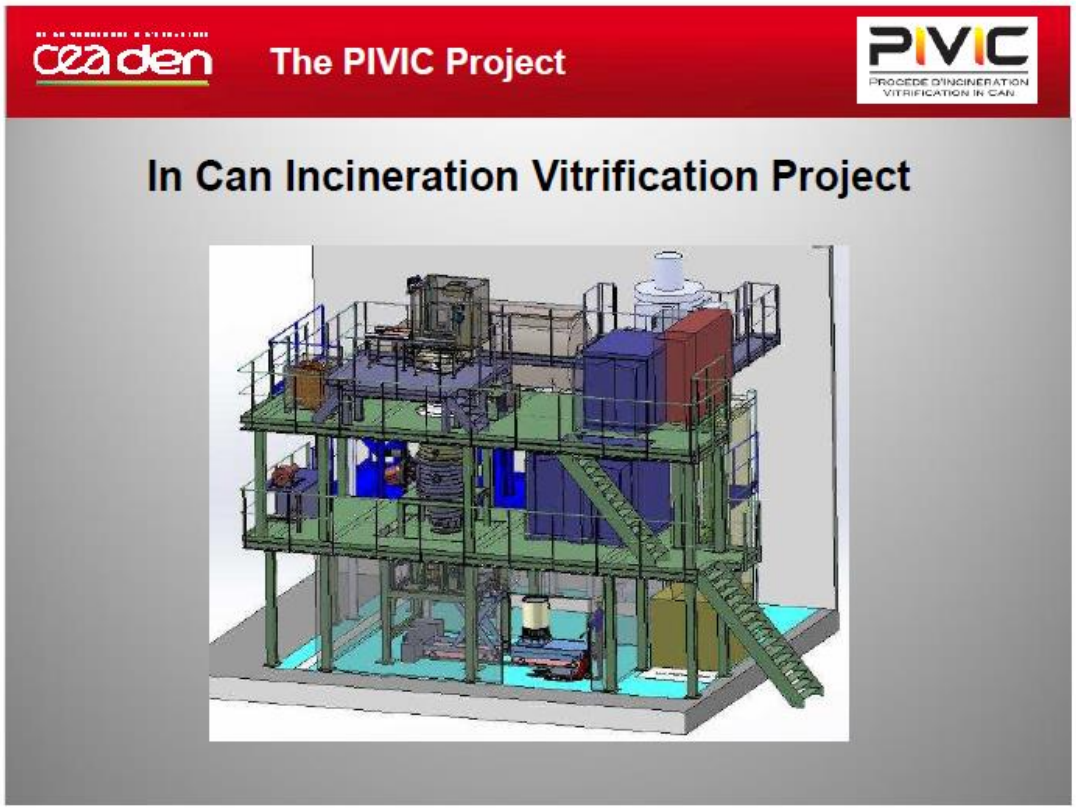


圖 12. PIVIC 系統

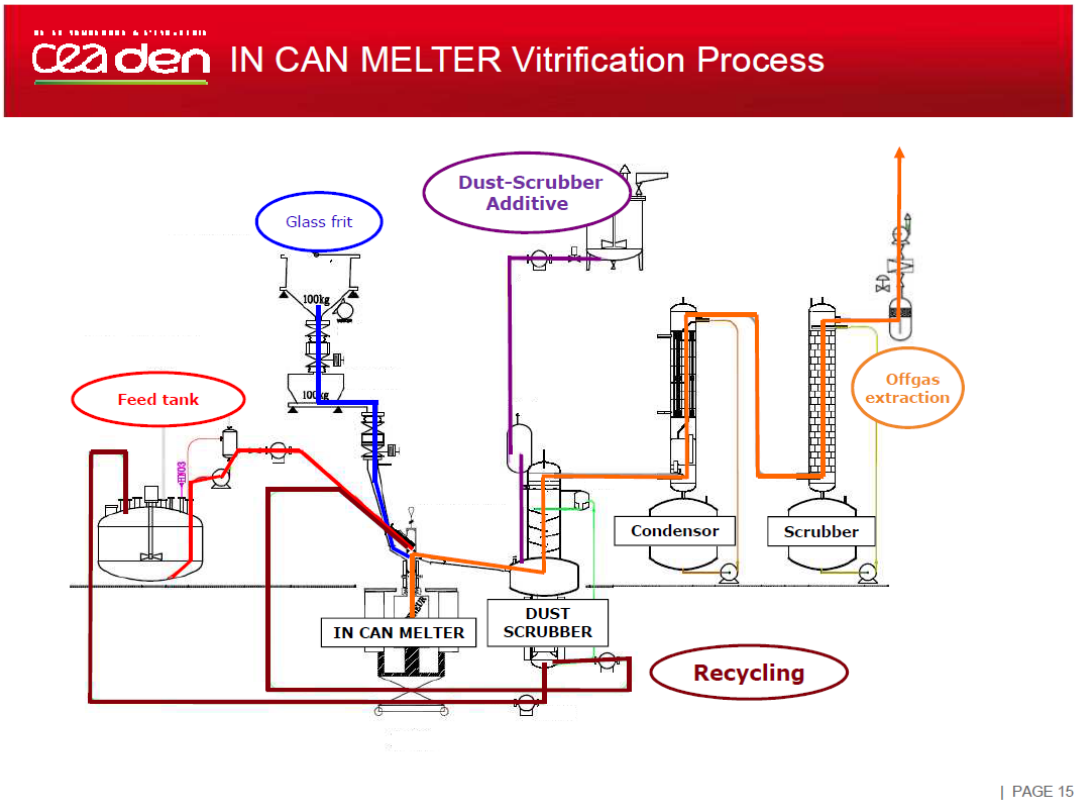


圖 13. DEM&MELT 系統

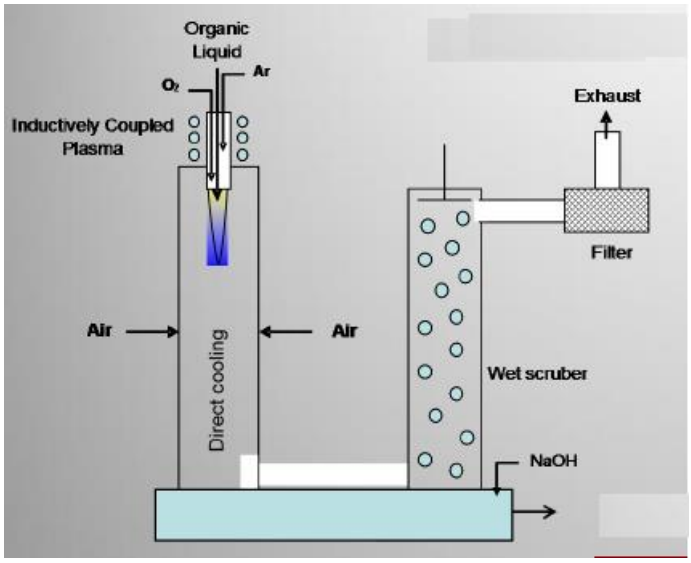


圖 14. 處理含鹵素有機液體裝置

日本 Toshiba 公司發表的 T-OZON$_{TM}$ 臭氧除污技術的進展，T-OZON$_{TM}$ 該是一種化學除污方法，該公司表示之前已應用於沸水式反應器(BWR)系統，現在要擴展至壓水式反應器(PWR)系統。海報中以鎳合金為例，說明除污機制，如圖 15 所示。在氧化開始的階段，鎳從靠近金屬旁氧化物層開始溶解，鉻氧化物開始生成；接著，持續以臭氧氧化，鉻從內層及氧化物層開始溶解氧化物，最後含鐵層生成。而這含鐵層很容易以草酸還原移除。但是可能還會有少量鐵氧化物存在，若是如此，則重複上述氧化還原步驟即可。與傳統其他氧化劑高錳酸鉀($KMnO_4$)及次氯酸(HClO)比較，結果如圖 16 所示。由於臭氧所溶解的鎳高於其他兩種，因此臭氧處理法最後含鐵層氧化物並未發現。另外，以無機酸調節臭氧反應 pH，發現作用效果以混合酸調節會優於單獨使用硝酸。至於所需臭氧濃度則由 CFD 模擬軟體推估。而目前此系統仍在持續改進中。

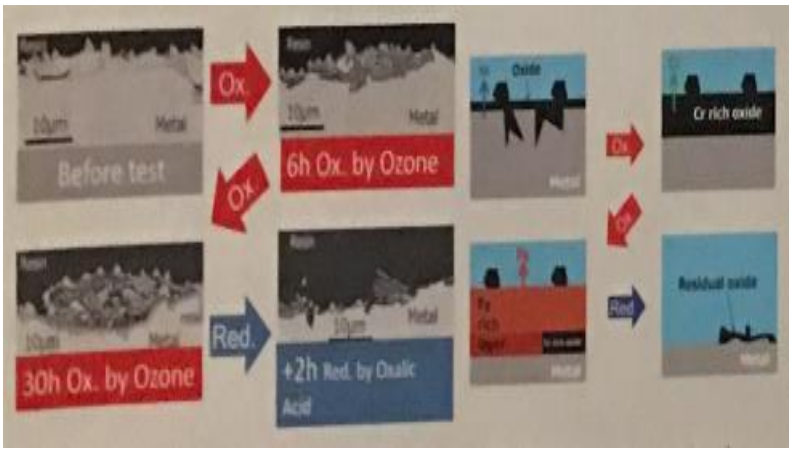


圖 15. 臭氧及草酸除污機制

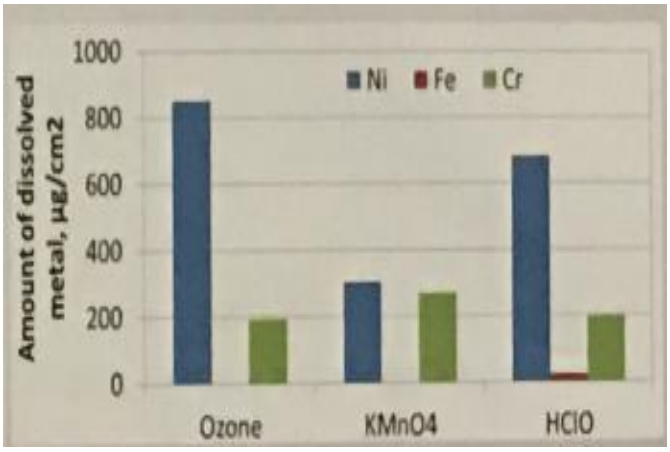


圖 16. 臭氧與其他氧化劑比較

其他議題

在參觀儀器設備展以及與專家討論時蒐集的資訊。

首先是有關容器的部分，美國阿崗國家實驗室(ANL)有發展一款智慧桶技術，將無線射頻辨識(RFID)技術應用於廢棄物管理上，於廢棄物貯存桶上裝有 RFID 標籤，據說內建的電池壽命可達 10 年之久，另外可呈現的數據包括桶子編號、標籤號碼、電池狀況、溫度、濕度、密封狀況及加馬(Gamma)劑量等，此 ARG-US RFID 概念始於 2007 年，2016 年拿到商業化貯存桶專利。

美國 Paragon 公司型號 9979-AF 容器可當包括固體與液體的運送與貯存容器，已經獲得 NRC 及 DOE 許可。美國 CPC 公司 (Container Products Corporation)，不同用途容器種類很多，包括 B-12、B-25 及 B-36 等、廠商提供的目錄見附錄五。

偵測儀器方面， Canberra 公司於會議中發表加馬偵測儀器的多種應用，首先是小型化偵測儀器，以利現場量測，如圖 18 所示，缺點是靈敏度會較差；另外是應用面變廣，包括煙囪氣狀物測量、桶槽或管線內的測量等。最特別的是，搭載於移動平台或無人機上的偵檢器，上述的應用分別如圖 19-21 所示。

美國 HI-Q Enviromental Products Company, INC. 原本是環境保護設備供應商，現在也提供放射性廢棄物除污產品，他們發表一系列偵測儀器產品(WAN 200/300)，可用於核電廠、廢棄物貯存庫、再濃縮工廠等，作為低放射性廢棄物或外釋的監測，其中一款 WAM-202 外觀如圖 22 所示。

圖 17. 具備 RFID 的智慧貯存桶

圖 18. 偵測儀器小型化

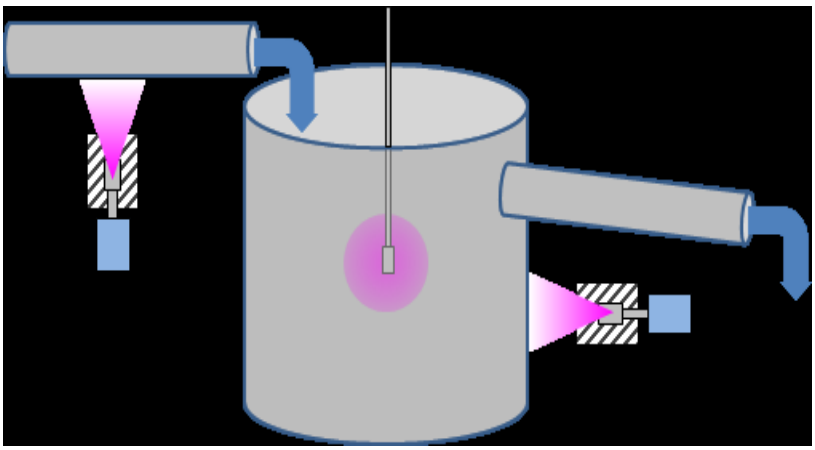


圖 19. 桶槽或管線內的測量

圖 20.用於移動平台的量測

圖 21.用於無人機上的量測

圖 22. HIQ 公司的 WAM-202 外觀

三、心得

1. 廢棄物管理研討會 (WM symposium)是目前放射性廢棄物處理及處置領域最重要技術交流平台，討論議題廣泛，參與人數多，代表性足，且含括美國能源部，是一個產、官、學研交流的平台。且大會累積多年舉辦經驗，於議程安排、會議場地及儀器展示方面都有精心設計的感覺，對首次參加此會議的我而言，這大會辦的很用心。會場中更是核能機構藉機推銷本身技術的最佳場所，藉發表相關研究論文與探討放射性廢棄物處理新技術，彼此之經驗得以直接溝通與交流。

2. 於會議期間與各國專家交流，感覺日本公司很積極，除了有發表新除污技術及參展外，對我國核電廠除役商機均顯得興趣十足，一直表示他們有除役經驗可供參考。這也讓我想到，因為我們沒有自己核能產業鏈，多依賴國外，以及國內市場小，因此無法吸引國內廠商投入，未來核電廠除役工作將會比較辛苦。

3. 此次大會主題為機器人大展，會中不少議題為自動化應用，尤其進行高階放射性廢棄物處理，避免工作人員所受劑量過高，是未來不可或缺的重要工具之一，因此所裡應該朝此方面加強研發，如引進或開發機器人(未必需要是人型自動化機器)進行切割或遠端操作。另外，有關美國 Argonne 國家實驗室的 RFID 貯存桶技術，可考慮將其應用至所裡低放射性廢棄物處理廠貯存庫，以有效掌控廢棄物貯存桶儲存狀況。

四、建議事項

1. 資訊與技術交流對身為研究機關的我們而言，是非常重要的，參加國外研討會，除了提升同仁國際觀外，當面請益或交流，建立研究人脈，日後工作有需要幫忙，應該較容易成功。由於本所每年均有派人參加此會議，建議維持，以便持續收集資訊。

2. 類似 WM 這類大型研討會議題廣泛，一人參加可能會有資訊遺漏的風險，或許兩人成行，效果會更好。

3. 電漿技術在除役的應用在 WM 一直有國外廠商於會議中發表最新進度，包括去年比利時 Belgoprocess 以及今年法國 CEA，顯示電漿技術仍有一定潛力，建議持續收集相關會議資料。

五、附錄

附錄一 大會邀請函

WM SYMPOSIA EDUCATION & OPPORTUNITY IN WASTE MANAGEMENT A NON-PROFIT ORGANIZATION

December 28, 2017

Chen, Yung-Chih
Institute of Nuclear Energy Research, R.O.C.
No.1000, Wenhua Rd., Longtan District
Taoyuan City 32546, Taiwan

Passport #: 314826089
Passport Expiration Date: 13 Mar 2027
Country of Issue: Republic of China
Date of Birth: 22 Aug 1967

Dear Yung-Chih,

This letter is an invitation to WM Symposia to participate in the WM2018 Conference to be held in Phoenix, Arizona during the week of March 18 – 22, 2018 and present paper #18201, entitled "Preliminary Plan of Radwaste Management for the Decommissioning of Chinshan NPP in Taiwan".

We hope that this letter can be used by you to secure your travel permissions and visas as required to travel to Arizona. We ask that US authorities extend all courtesies to you for travel and in processing your travel requests.

Please contact me if you have any questions on this matter. I look forward to meeting you in Phoenix in March.

Sincerely,

Jan Carlin
WM SYMPOSIA, INC.
Managing Director

附錄二 WM 會議議程

Schedule of Events

All events will take place at the Phoenix Convention Center – West Building, unless otherwise noted.

Saturday, March 17, 2018

0700 - 2000	Guest/Attendee Tour: Grand Canyon Tour** - Buses load at 0645
0800 - 1500	Exhibitor Move-In - *Lower Level, Ex Hall 4*
1100 - 1700	Registration Open - *Lower Level, Ex Hall 4*
1300 - 1900	Satellite Registration Desk Open - *Marriott Renaissance Lobby*
1300 - 1900	Satellite Registration Desk Open - *Hyatt Regency Lobby*
1600 - 1715	Track Meeting - *Hyatt Regency Phoenix, Regency AB*
1730 - 2100	PAC Meeting and Dinner - Sponsored by Walischmiller Engineering GmbH and NuVision Engineering - *Hyatt Regency Phoenix, Regency CD*

Sunday, March 18, 2018

0700 - 1800	Presenter and Co-Chair Check-in - *Level One, 105C*
0730 - 1730	Workshop - US EPA Superfund Site Remediation Program Radiation Risk Assessment Training - *Level One, 106B*
0800 - 2000	Registration Open - *Lower Level, Ex Hall 4*
0800 - 1400	Exhibitor Move-In, Hand Carry Only - *Lower Level, Ex Hall 4*
0800 - 1500	WMS Board of Directors Meeting - *Hyatt Regency Phoenix, Ellis Room*
0800 - 1630	Roy G. Post Foundation Benefit Golf Tournament* - *The Legacy Golf Club, Phoenix*
0800 - 1700	Satellite Registration Desk Open - *Marriott Renaissance Lobby*
0800 - 1700	Satellite Registration Desk Open - *Hyatt Regency Lobby*
1000 - 1400	Guest/Attendee Tour: Desert Hike Tour** - Buses load at 0945
1100 - 1700	Workshop - Safety Culture - A Common Construct Requiring Commitment from the Board Room to the Shop Floor - *Level One, 106C*
1530 - 1645	IPAC Meeting - *Level One, 102A*
1600 - 1700	Student Assistant Training - *Level One, 101C*
1630 - 1700	WM2018 Conference Orientation for New Attendees - *Lower Level, Panel Zone, Ex Hall 4*
1700 - 2000	Show Floor Open & Welcome Reception - Sponsored by Jacobs CH2M - *Lower Level, Ex Hall 4*

Monday, March 19, 2018

0630 - 1800	Registration Open - *Lower Level, Ex Hall 4*
0700 - 0800	Presenter's Breakfast - *Level Three, 301A*
0700 - 1800	Presenter and Co-Chair Check-in - *Level One, 105C*
0800 - 0945	Opening Plenary Session - Sponsored by North Wind Group - *Level Three, 301CD*
0930 - 1830	Show Floor & Student Connection Zone Open - *Lower Level, Ex Hall 4* *(Hall Closed from 1200 - 1300)*
0945 - 1030	Refreshment Break - Sponsored by Leidos - *Lower Level, Ex Hall 4*
1000 - 1700	Technical Sessions - *Level One & Panel Zone, Ex Hall 4*
1200 - 1300	Keynote Luncheon - *Level Three, 301BCD*
1300 - 1345	Dessert Service - *Lower Level, Ex Hall 4*
1330 - 1700	Student Poster Competition - *Lower Level, Ex Hall 4*
1445 - 1530	Refreshment Break - Sponsored by Merrick - *Lower Level, Ex Hall 4*
1700 - 1830	WMS Evening Reception - Sponsored by Westinghouse Government Services - *Lower Level, Ex Hall 4*
1800 - 1930	Students & Young Professionals Networking Reception - Sponsored by BWX Technologies - *Lower Level, Ex Hall 4 Near Student Posters - this event is open to all attendees!*

Tuesday, March 20, 2018

0630 - 1800	Registration Open - *Lower Level, Exh Hall 4*
0700 - 0800	Presenter's Breakfast - *Level Three, 301A*
0700 - 1800	Presenter and Co-Chair Check-in - *Level One, 105C*
0825 - 1700	Technical Sessions - *Level One & Panel Zone, Ex Hall 4*
0930 - 1830	Show Floor & Student Connection Zone Open - *Lower Level, Ex Hall 4* *(Hall Closed from 1200 - 1300)*
0945 - 1030	Refreshment Break - Sponsored by Wagstaff Applied Technologies - *Lower Level, Ex Hall 4*
1200 - 1300	Honors & Awards Luncheon - *Level Three, 301CD*
1300 - 1345	Dessert Service - *Lower Level, Ex Hall 4*
1445 - 1530	Refreshment Break - Sponsored by AECOM - *Lower Level, Ex Hall 4*
1700 - 1830	WMS Evening Reception - *Lower Level, Ex Hall 4*

Schedule of Events - Continued

All sessions will take place at the Phoenix Convention Center – West Building, unless otherwise noted.

Tuesday, March 20, 2018 - Continued

1800 - 2030	Women of Waste Management (WoWM) Panel & Networking Reception - Sponsored by Fluor - *Second Level, 212ABC*

Wednesday, March 21, 2018

0630 - 1800	Registration Open - *Lower Level, Ex Hall 4*
0700 - 0800	Presenter's Breakfast - *Level Three, 301A*
0700 - 1800	Presenter and Co-Chair Check-in - *Level One, 105C*
0825 - 1700	Technical Sessions - *Level One & Panel Zone, Ex Hall 4*
0930 - 1330	Show Floor & Student Connection Zone Open - *Lower Level, Ex Hall 4*
0945 - 1030	Refreshment Break - Sponsored by TradeWind Services - *Lower Level, Ex Hall 4*
1200 - 1325	Luncheon & Exhibitor Raffle Drawings - Sponsored by Spectra Tech Inc - *Lower Level, Ex Hall 4*
1330 - 2100	Exhibitor Move-Out - *Lower Level, Ex Hall 4*
1445 - 1530	Refreshment Break - *Level One, Foyer*
1800 - 2100	Wednesday Evening Networking Event* - *The Heard Museum - Buses load at 1745***

Thursday, March 22, 2018

0630 - 1700	Registration Open - *Level One, 105C*
0700 - 0800	Presenter's Breakfast - *Level Three, 301A*
0700 - 0815	PAC Meeting - Part 1 - *Level Three, 301A*
0700 - 1800	Presenter and Co-Chair Check-in - *Level One, 105C*
0730 - 0810	Refreshment Break - *Level One, Foyer*
0825 - 1700	Technical Sessions - Level One
1200 - 1315	Thursday Luncheon - *Level Three, 301A*
1200 - 1300	PAC Meeting - Part 2 - *Level One, 102BC*
1325 - 1700	Topical Panel Session #124 - Management of Used Nuclear Fuel: Will the United States Reengage and Align with International Efforts - *Level One, 102BC*
1445 - 1530	Refreshment Break - *Level One, Foyer*
1700 - 1800	Closing Reception - Sponsored by Advoco Professional Services - *Level One, Foyer*
1730 - 1830	Optional PAC Meeting - Part 3 - *Hyatt Regency, Cowboy Artist's Room*

Friday, March 23, 2018

0830-1300	US Nuclear Regulatory Commission Public Meeting - *Phoenix Convention Center, Room 211A*

Schedule Subject to Change
Separate Registration Fees Apply
**** All buses for off-sites events & tours will load from the Hyatt Regency Phoenix Monroe Street exit.***

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Technical Program

Session #	Technical Program - Schedule at a Glance – As of February 23, 2018 **Annotated Session Titles** *(for full session titles, please see individual listing)*	Time	Room	1: Policies/Programs	2: HLW/SNF/TRU	3: LA/LW, NORM	4: Nuclear Power Pl.	5: Package/Trans.	6: D&D	7: Environ. Rem.	8: Commun., E & T	9: Special Topics	Robotics/Remote Tec.
	Monday Morning, March 19			**The 9 WM Tracks for Subject Reference**									
1	Waste Management Symposium 2018 Plenary Session	0800	301CD	X									
2	Panel: Hot Topics in US DOE - EM	1000	102ABC	X									
3	Panel: US DOE-EM Robotics (1/8)	1000	105AB	X									X
4	Panel: Challenges & Innovations in Radwaste Packaging, Transp & Compliance	1000	103AB					X					
5	Panel: Interagency Community of Practice in Risk and Performance Assessment	1000	104AB									X	
6	HLW, SNF/UNF and Long-Lived Alpha/TRU Programs and Policies	1000	101B		X								
7	Hanford HLW Treatment and Immobilization Plant Update	1000	101C		X								
8	Waste Management in Mining, Uranium Industry, Oil & Gas & Non-Nuclear Sectors	1000	101A			X							
9	D&D of US DOE Facilities	1000	106A						X				
10	Environmental Remediation in Urban and Suburban Environments	1000	106B							X			
11	Communication of Technical Issues: Worldwide Experiences	1000	106C								X		
12	ANDR Country Update and Procurement Request for a General Consultant	1000	Ex Hall	X									
	Monday Afternoon, March 19												
13	Panel: Robotics - Exoskeleton (Worker Augmentation) (2/8)	1350	105AB	X									X
14	Merged with Session 13												
15	Robotics: Programmatic Elements (1/11)	1350	101A	X									X
16	Panel: LANL Recovery - Re-Treatment of TRU Problem Waste Streams (1/4)	1350	102BC		X								
17	Panel: US DOE WIPP: Return to TRU Waste Operations Following 2014 Incidents	1515	102BC		X								
18	Panel: Small Business Procurement & Contracting Opportunities within DOE (1/6)	1350	Ex Hall	X									
19	Panel: Doing Business with the US DOE (2/6)	1515	Ex Hall	X									
20	Operating Experience in the Treatment & Storage of LLW/ ILW	1350	101C			X							
21	Panel: Hot Topics in US Commercial LLW Management	1350	103AB			X							
22	Panel: EFCOG - Avoiding the Human Capital Cliff in the DOE Complex	1515	103AB	X									
23	Selected Key Topics in US Commercial LLW Management	1515	101C			X							

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Technical Program - Continued

Session #	Technical Program - Schedule at a Glance – As of February 23, 2018 **Annotated Session Titles** *(for full session titles, please see individual listing)*	Time	Room	1: Policies/Programs	2: HLW/SNF/TRU	3: LILW, NORM	4: Nuclear Power Pl.	5: Package/Trans.	6: D&D	7: Environ. Rem.	8: Commun., E & T	9: Special Topics	Robotics/Remote Tec.
24	Panel: Implementing Technically-Based Cleanup	1350	104AB							X			
25	Panel: UK – Remediation of Sellafield Legacy Ponds and Silos	1515	104AB							X			
26	Sustainable Remediation Processes - Global Insights or Applications	1350	106A							X			
27	Modeling Applications in Environmental Remediation	1515	106A							X			
28	Radioactive Material Packaging and Transportation Regulatory Issues	1350	106B					X					
29	Packaging, Transportation & Related Safety Programs and their Implementation	1515	106B					X					
30	Plans for and Experience in Transitioning from Operations to Decommissioning	1350	106C						X				
31	Recovery from Failure of HLW Infrastructure	1350	102A		X								
32	Low Activity Waste (LAW) Pretreatment Process Update	1515	102A		X								
33	Integrated Performance & Risk Assessments, Decision Analyses & Risk Mgmt	1350	101B									X	
34	Posters: HLW, SNF/UNF and Long-Lived Alpha/TRU Waste	1350	1-Foyer		X								
35	Student Posters: The Next Generation - Industry Leaders of Tomorrow	1330	Ex Hall	X									
	Tuesday Morning, March 20												
36	Panel: Environmental Management Activities and Programs at LANL (2/4)	0825	102BC	X									
37	Panel: Waste Management Programs Supporting the Mission at LANL (3/4)	1015	102BC	X									
38	Panel: Aligning Decision-Making to Deliver Timely Results	0825	103AB	X									
39	Panel: Transition to GOCO at Canadian Nuclear Laboratories	1015	103AB	X									
40	Panel: Emerging Middle East Nuclear States' Status and Plans	0825	104AB	X									
41	Panel: Nuclear Power Plant Waste Management - LLW Processor Issues	1015	104AB				X						
42	Panel: US DOE Spring Quarterly Business Opportunity Forum (3/6)	1000	Ex Hall	X									
43	Panel: International Innovations in Robotic Decommissioning Technology (3/8)	0825	105AB						X				X
44	Robotics: Application of Innovative D&D Technology (2/11)	0825	106A						X				X
45	Robotics: Wearable Robotics and Exoskeletons (3/11)	0825	101A	X									X
46	Storage and Retrieval of SNF/UNF	0825	106B		X								

Technical Program - Continued

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47	Operational Safety Issues in the Implementation of Deep Geological Repositories	0825	106C		X								
48	Assessment of Disposal Systems, Facilities and Sites for LLW/ILW	0825	101B			X							
49	Environmental Remediation Progress Toward Closure of Contaminated Sites	0825	101C							X			
50	Innovations and Performance Solutions to Workplace Management	0825	102A								X		
51	Posters: LLW/ILW/NORM/TENORM/Depleted Uranium/ Mixed Waste	0825	1-Foyer			X							
52	Posters: NPP Waste Management and On-Site SNF/UNF Storage	0825	1-Foyer				X						
	Tuesday Afternoon, March 20												
53	Surface Water Management & Groundwater Remediation Activities at LANL (4/4)	1350	102A	X									
54	Panel: Japan Fukushima Daiichi Decommissioning Update (1/2)	1350	102BC	X									
55	Panel: Update on the Revitalization of Fukushima and The Surrounding Area (2/2)	1515	102BC	X									
56	Panel: US DOE LLW On-Site Disposal: LLW Disposal Facility Federal Review	1350	105AB			X							
57	Panel: Challenges in US DOE HLW Tank Management	1515	105AB		X								
58	Panel: Waste Management Planning for Utility Small Modular Reactors (SMRs)	1350	103AB				X						
59	Panel: US Nuclear Power Plant Waste Management - US LLW Disposal Issues	1515	103AB				X						
60	Panel: Robotics - DOE-EM Robotics and Emerging Technologies Roadmap (4/8)	1350	Ex Hall	X									X
61	Panel: Hot Topics in Small Business Contracting in US Waste Management (4/6)	1515	Ex Hall	X									
62	Robotics: Current Use and State of Art (4/11)	1350	101A	X									X
63	Panel: Graduating Students and New Scientists and Engineers - Wants & Needs	1350	104AB								X		
64	Panel: Young Professionals in Nuclear - An International Perspective	1515	104AB								X		
65	Groundwater Remediation Projects - Worldwide Experiences	1350	106A							X			
66	Crosscutting Subsurface Mass Transport and Environmental Assessment	1515	106A									X	
67	D&D of Nuclear and Non-Power Generating Facilities	1350	106B						X				
68	Latest Issues and Developments in Geologic Repositories in Salt Rock	1350	101C		X								
69	Emerging Treatment, and Storage Technologies for LLW/ILW Worldwide	1350	101B			X							

Technical Program - Continued

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70	Package Design	1350	106C					X					
71	Posters: Packaging and Transportation	1350	1-Foyer					X					
72	Posters: Environmental Remediation	1350	1-Foyer							X			
73	Posters: Communications, Involvement, Education and Training	1350	1-Foyer								X		
	Wednesday Morning, March 21												
74b	Panel: U.S. Nuclear Robotics: Yesterday, Today, Tomorrow (5/8)	0825	105AB	X									X
75	Robotics: Applied D&D (5/11)	0825	101A	X									X
76	Panel: Dealing with Problematic DOE Mixed Waste Streams and Policy Changes	0825	102BC			X							
77	Panel: US NRC – Current and Emerging US NRC LLW Regulatory Topics	1015	102BC			X							
78a	Withdrawn for WM2018												
78b	Modeling and Optimization of Hanford HLW and LLW Treatment Processes	0825	103AB		X								
79	Panel: ER Progress Toward Closure of Contaminated Sites	1015	103AB							X			
80	Panel: Agency Perspectives on the Use of Risk and Dose Assessment Tools	0825	104AB									X	
81	Panel: Progress on Deep Repository Programs Around the World	1015	104AB		X								
82	Panel: US DOE Procurement and Contracting Opportunities (5/6)	1015	Ex Hall	X									
83	TRU Waste Disposition	0825	101C		X								
84	Instrumental Waste Characterization Methods for LLW/ILW	0825	102A			X							
85	Technical Innovations in Environmental Remediation and Site Closure	0825	106A							X			
86	Global Experience of RK&M for Nuclear Waste Geologic Repositories	0825	106B								X		
87	Advances in the Management of NPP Dry Waste from Around the World	0825	106C				X						
88	Robotics: Remote System Handling and Robotics for Commercial NPPs (6/11)	1015	106C				X						X
89	Advancements in HLW Separations and Reprocessing	0825	101B		X								
90	D&D of US DOE Facilities	1015	101B						X				
91	Posters: D&D	0825	1-Foyer						X				
92	Posters: Special Topics and Track Cross Cutting Technology Topics	0825	1-Foyer									X	X

Technical Program - Continued

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	Wednesday Afternoon, March 21												
93a	Panel: Collaboration Across Borders to Deliver Cleanup and D&D Challenges	1325	102BC	X									
93b	Engineering and Design for Geologic Disposal	1515	102BC		X								
94	Panel: DOE Mission Success through Application of Practices and Solutions	1325	105AB	X									
95	Robotics: Next Generation and RDDT&E (7/11)	1325	101A	X									X
96	Panel: Challenges in Cask Design and Certification - International Perspectives	1325	103AB					X					
97a	Withdrawn for WM2018												
97b	US ACE - Deactivated NPP Program D&D Contracting Opportunities (6/6)	1500	103AB						X				
98	Panel: Leveraging Innovations in Science & Technology to Benefit Safety (6/8)	1325	104AB									X	X
99	Panel: Implementation Approaches & Expectations for Radwaste Management	1515	104AB								X		
100	UK EPSRC DISTINCTIVE Research Programme	1325	106C									X	
101	Nuclear Power Plant Onsite SNF/UNF Storage ISFSIs and Failed Fuel Handling	1325	106B				X						
102	International Experience in Waste Optimization and Harmonization During D&D	1325	106A						X				
103	Characterization and Remediation Technologies for Complex Contaminants	1325	101B							X			
104	Withdrawn for WM2018												
105	Infrastructure Improvements in Aging Facilities	1515	102A		X								
106	Analytical Waste Characterization Methods for LLW/ILW	1325	101C			X							
107	LLW/ILW - An International Perspective of WM Planning & Disposal	1515	101C			X							
108	Non-Paper Poster Topic for Emerging Issues	1325	1-Foyer										
	Thursday Morning, March 22												
109	Panel: US DOE EM Featured Office - Portsmouth/ Paducah Project Office	0825	102BC	X									
110a	Panel: Lessons Learned from Industrial Robotics Deployment (7/8)	0825	105AB									X	X
110b	Robotics: Software, Operating Systems, Sensors and All Realities, (8/11)	0825	103AB	X									X
111	Robotics: Mods to Commercial Systems & Remotely Operated Vehicles (9/11)	0825	101A	X									X
112	Worldwide Perspectives of Radioactive Waste Management	0825	101B	X									

Technical Program - Continued

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113	Merged with 93b												
114	Withdrawn for WM2018												
115	Development and Evaluation of Glass and Alternate Waste Forms	0825	104A		X								
116	Technology Alternatives for HLW Stabilization	1015	104A		X								
117	Storage and Retrieval of High-Level Tank Waste	0825	104B		X								
118	Roundtable: US DOE LLW Management - Energy Facilities - EFCOG WM	0825	101C			X							
119	SNF/UNF Transportation System Development	0825	106A					X					
120	D&D of Nuclear Power Plants	0825	102A						X				
121	The Impact of Citizens and Regulators on Radioactive Waste Issues	0825	106B								X		
122	Citizens Advisory Boards, Panels and Long-Term Safety Experience	1015	106B								X		
123	FUSRAP and US Army Corp Engineering Projects	0825	106C							X			
	Thursday Afternoon, March 22												
124	Panel: Management of SNF/UNF	1325	102BC		X								
125	Panel: Remotely Operated Vehicles for Emergency & Operational Response (8/8)	1325	105AB	X									X
126	Robotics: Simultaneous Localization/Mapping & Geolocation Visualization (10/11)	1325	101A	X									X
127	Process Monitoring for HLW Treatment	1325	102A		X								
128	Merged with Session 78b												
129	Storage & Processing of High Activity Waste	1515	102A		X								
130	Global Use of Cementitious Waste Forms for LLW/ILW	1325	101B			X							
131	The Use of Process Knowledge & Records for LLW Management Decision Making	1515	101B			X							
132	Regulatory & Programmatic Issues & Solutions for VLLW, LLW & ILW Worldwide	1325	101C			X							
133	Advances in Packaging Capabilities	1325	104A					X					
134	Perspectives on Management of Nuclear Power Plant Liquid and Wet Waste	1515	104A				X						
135	Robotics: Application of Innovative D&D Technologies & Remote Systems (11/11)	1325	103AB						X				X
136	Application of Innovative D&D Technologies	1325	104B						X				
137	Advancement in Technical Education and Training	1515	104B								X		
138	Innovative Field Monitoring for Environmental Remediation	1325	106A							X			

Technical Program - Continued

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139	Global Perspectives on Advances in Nuclear Safety Management	1325	106B									X	
140	Project Management Improvements-Planning through Completion	1515	106B									X	
141	Radiological Dispersion Devices and Weapons of Mass Destruction	1325	106C									X	

Technical Program Schedule:

Start times listed for paper presentations are fixed. The Session Co-chairs will try to manage each paper to the published start time in the Final Program. If a paper is withdrawn, the remaining presentations will **NOT** move up in time.
There may be gaps of 25-50 minutes in a session due to cancellations (1-2 papers)!

The name **bolded** by a paper is the proposed presenter.


Logo Indicates the WM2018 Theme, a Robotics/Remote System Presentation

附錄三 DOE 海報


U.S. DEPARTMENT OF ENERGY
OFFICE OF ENVIRONMENTAL MANAGEMENT
Mobile Robotic Survey System
Non-Contact Nuclear Material Operations at TA-55
Objective
Create specifications for the system, perform design Develop an introductory mobile robotic system for service in the Los Alamos National Laboratory TA-55 nuclear material vault to increase worker safety and reduce radiation dosage.
Development Overview
Create specifications for the system, perform design work, and head software development. The target goals of the final system include manipulation and transportation of nuclear material containers within the vault. Development work in these areas continues at the University of Texas at Austin on a variety of testbed robotic platforms.
Radiation Survey at Portsmouth Gaseous Diffusion Plant
Localization and Navigation – PioneerLX
• 2D LIDAR, an internal gyroscope, and precision wheel encoders for navigation
• Four pairs of ultrasonic sonar sensors on front, and rear- and front-bumper switch for obstacle detection, avoidance, and collision mitigation
• Uses Monte Carlo Localization Algorithm with an extended Kalman filter, while navigation to target poses is accomplished using a grid-based search, possibly similar to Dijkstra's Graph Search Algorithm
• Autonomous docking and recharging
User Interface with Camera Feed and Radiation Heat Map
Radiation Survey and Inspection System
4
1
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2001-Apr-26
2005-Jan-08
Barcode and Object Recognition
Where We Are Now
Work continues toward deployment of the PioneerLX systems for cold testing and operating training, while development continues at UT on innovative additional functions and improvements to existing capabilities in all areas discussed.
innovation technology environmental management
Los Alamos NATIONAL LABORATORY EST. 1943
ROS
THE UNIVERSITY OF TEXAS AT AUSTIN
Cockrell School of Engineering

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Design and Evaluation of a Remote Aerial Vehicle

Exploration of a cluttered indoor environment with a micro-aerial vehicle.

Challenges

- Indoor operation precludes GPS
- Dynamic lighting and occlusion cause visual odometry to fail
- Transient flow can compromise aircraft controller
- Intermittent connectivity can challenge direct operator control over vehicle

Aging national nuclear infrastructure sites are inaccessible to human inspectors due to physical constraints or high radiation levels.

Core Capabilities

Adaptive Teleoperation

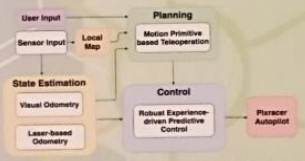
- Uses motion primitives to smoothly map inputs from human operator to desired vehicle trajectories
- Strategy translates high-level user inputs into safe, feasible trajectories

Experience-Driven Predictive Control

- Fast, robust control strategy that accounts for changes to the robot's dynamics with an online perturbation model
- A set of controllers are generated and adapted in real time, based on dynamics modeling error
- A locally optimal controller is selected and parameterized at each control iteration, allowing the aircraft to improve its flight performance through experience

Multi-Modal State Estimation

- Visual odometry with RGB-D sensor provides accurate estimates agnostic to environmental structure but brittle to lighting changes
- Laser odometry provides accurate indoor tracking in structured environments with dynamic lighting
- Sensor observations are fused leveraging advanced Unscented Kalman Filter, which can handle asynchronous observations



Block diagram of Inspection System Architecture

Where We Are Now

- Individual subsystems verified through simulation and experimental validation
- Incorporation of laser- and vision-based state estimation into a unified framework is currently underway
- Studying the impact of noise and uncertainty on the control strategy to enhance flight performance in varying environmental conditions in degraded flight conditions

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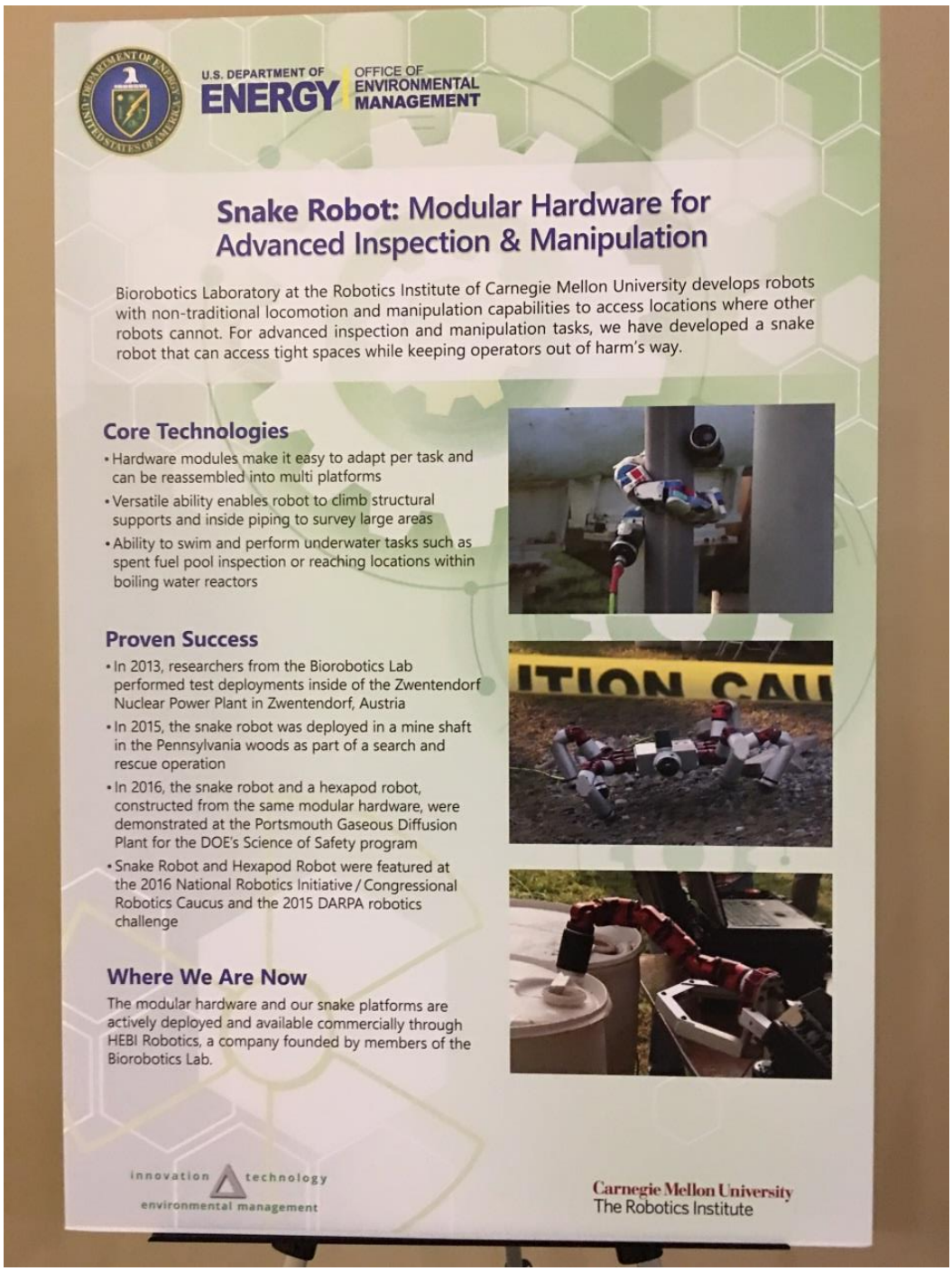
Carnegie Mellon University

Savannah River National Laboratory


U.S. DEPARTMENT OF ENERGY
OFFICE OF ENVIRONMENTAL MANAGEMENT
Snake Robot: Modular Hardware for Advanced Inspection & Manipulation
Biorobotics Laboratory at the Robotics Institute of Carnegie Mellon University develops robots with non-traditional locomotion and manipulation capabilities to access locations where other robots cannot. For advanced inspection and manipulation tasks, we have developed a snake robot that can access tight spaces while keeping operators out of harm's way.
Core Technologies
• Hardware modules make it easy to adapt per task and can be reassembled into multi platforms
• Versatile ability enables robot to climb structural supports and inside piping to survey large areas
• Ability to swim and perform underwater tasks such as spent fuel pool inspection or reaching locations within boiling water reactors
Proven Success
• In 2013, researchers from the Biorobotics Lab performed test deployments inside of the Zwentendorf Nuclear Power Plant in Zwentendorf, Austria
• In 2015, the snake robot was deployed in a mine shaft in the Pennsylvania woods as part of a search and rescue operation
• In 2016, the snake robot and a hexapod robot, constructed from the same modular hardware, were demonstrated at the Portsmouth Gaseous Diffusion Plant for the DOE's Science of Safety program
• Snake Robot and Hexapod Robot were featured at the 2016 National Robotics Initiative / Congressional Robotics Caucus and the 2015 DARPA robotics challenge
Where We Are Now
The modular hardware and our snake platforms are actively deployed and available commercially through HEBI Robotics, a company founded by members of the Biorobotics Lab.
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Carnegie Mellon University
The Robotics Institute

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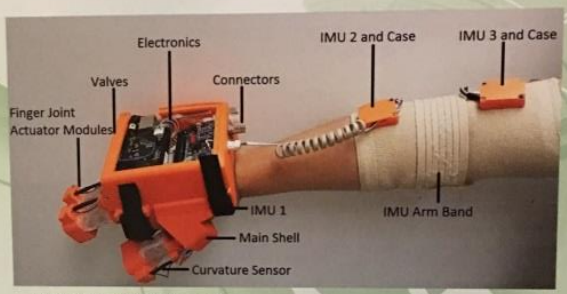
Soft Robotic Haptic Gloves for Intuitive Robot Teleoperation

Worcester Polytechnic Institute is the first university in the U.S. to offer an undergraduate robotics major. Dr. Cagdas Onal is the director of the Soft Robotics Lab and recently co-founded the Human Augmentation Laboratories in the Mechanical Engineering Department and Robotics Engineering Program. The laboratories support the personnel and required equipment for modeling, design, fabrication, numerical simulation, and experimental verification of the proposed soft robotic haptic glove system and associated algorithms.

Core Technologies

- Provides a natural interface to remote-control a robotic arm or a virtual reality simulation through haptic feedback
- Measures joint angles from a user's arm, wrist, and fingers to control a 6 degree-of-freedom robotic arm and/or a simulation
- Reports the forces present in hand-object interactions to the glove, which applies these to the user's fingers and wrist using pneumatic actuators
- Attempts to close the human-robot gap by providing integrated haptic force feedback
- Untrained users attempting to keep hold of a simulated floating ball to test the haptic glove prototype found that they were unable to complete this task without haptic feedback



The system consists of the haptic glove, a haptic wrist attachment, and multiple inertial measurement units (IMUs) that report the angle of the user's arm and hand

In this first stage of simulation, the mounted arm can interact with objects like the red ball shown

The fingers on the haptic glove directly control the gripper on a robotic arm, enabling natural grasping.

Where We Are Now

- Glove prototype, simulation, and arm can work together to perform simple tasks
- Plan to extend simulation through a virtual reality environment and headset, and extend the system to perform more complex tasks like using tools

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WPI

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Cooperative Control of Humanoid Robots for Remote Operations in Nuclear Environments

Glovebox clean-up – a common operation in nuclear facilities – poses potential contamination hazards to workers. The use of robotics under human supervision could provide a safer alternative. This work aims to develop a cooperative control strategy for NASA's humanoid robot, **Valkyrie**, to perform glovebox clean-up tasks.

Human-Supervised Humanoid Control

- Whole-body controller is implemented that relies on online optimization to generate behaviors, such as autonomous balancing
- Robot's arm contacts with the glovebox can be exploited while performing dual-arm manipulation to assist with balancing and lifting heavy objects

Valkyrie

Constrained Motion Planning and Control for Risk-Averse Task Completion

- Motion planner considers constraints of a glovebox: physical constraints (e.g., reduced workspace and robot posture with arms through gloveports) and virtual constraints (e.g., reduced perception, field of view)

Human-Robot Interaction Design with an Interface Using Multi-Modal and Fused Information Displays

- Operator can gain situation awareness by using virtual reality devices (e.g., headsets, control gloves) to maneuver through fused sensor displays of point clouds and camera images
- Touch sensors in the robot's hands with added capacitive sensors
- Display of combined sensor modalities can enable the operator to "see through" the robot's hands to the objects being manipulated. performance through experience

Workers sort through exhumed waste in a glovebox at the Idaho Site's Pit 9

Valkyrie has 44 degrees of freedom, weighs 300 pounds, and stands 6' 2" tall.

The project is supported by the Department of Energy, by the National Aeronautics and Space Administration issued through the Science and Technology Mission Directorate, and by the National Science Foundation.

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U.S. DEPARTMENT OF ENERGY
OFFICE OF ENVIRONMENTAL MANAGEMENT
DARPA Hand: A Low-Cost Robotic Hand Performing Highly Dexterous Tasks in Hazardous Environments
Design
• Hand frame supports set of finger modules, magnetically attaching/detaching
• Finger modules contain sensor systems enabling hand to perform complex manipulation tasks
• Imaging systems increases function and performance
• Control realized through autonomous software, semi-autonomous collaboration with high-level human input, and low-level human control via teleoperation
Supports
• Counter-IED
• Countermine
• Explosive Ordnance Disposal
• Search and Rescue
• Casualty Care
• Extreme Environments
Core Technologies
• Grasping and picking up objects
• Sorting objects
• Drilling holes
• Throwing objects
• Sliding objects
• Inserting objects
• Turning wheels, knobs, levers
• Holding objects
• Assembling object from part kits
• Removing objects from small spaces
Features
Low Cost: 3D high-resolution rapid prototyping technologies
Dexterous: 3 degree-of-freedom (DOF) fingers
Modular: Hand frame with identical finger modules that attach through magnetic attachment with electrical power
Benefits
Mechanical Breakaway: Fingers robustly separate from palm in overload conditions
Reduced Down Time: It's easy to swap out fingers when repairs are needed (versus repairing the entire hand)
Customizable: Limitless variation in palm geometry using the same fingers
innovation technology
environmental management
Sandia National Laboratories

附錄四 論文摘要

WM2018 Conference, March 18 – 22, 2018, Phoenix, Arizona, USA

Preliminary Planning of Radwaste Management for the Decommissioning of Chinshan NPP in Taiwan – 18201

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ABSTRACT

The Chinshan NPP was the first commercially operated nuclear power plant in Taiwan since 1978. There are two BWR units in Chinshan NPP, which each unit has electrical output of 636 MWe. After 40 year's period of license, the final shutdown date of Unit No. 1 and Unit No. 2 will be in December, 2018 and in July, 2019, respectively. According to "Nuclear Reactor Facilities Regulation Act" in Taiwan, decommissioning of nuclear reactor facilities should be implemented by the strategy of DECON (Decontamination followed by dismantling) within 25 years when the permission is approved by Atomic Energy Council (AEC). The decommissioning plan of Chinshan NPP has been permitted by AEC in the end of June, 2017. The implementation of Chinshan NPP decommissioning will be started while the Environmental Impact Assessment is approved by EPA. In this study, the Turbine Building in Chinshan NPP is selected as a case study for the preliminary planning of decommissioning. First, we thoroughly examine the inventory of all macro-components in the Turbine Building to estimate the waste amounts. Accordingly, the work breakdown structure (WBS) for dismantling of facilities is scheduled. Then, considering to minimize waste amounts, several suitable decontamination techniques, such as chemical and mechanical methods, which are developed by INER are considered to be adopted. As for the estimation of man hours of dismantling facilities, all events during the decommissioning tasks are classified into 16 work procedures and appropriative factors of corresponding team hours are gotten. In addition, the detailed methodology of the preliminary plan of decommissioning is also discussed. Finally, we hope the results of this planning can provide practical benefits to upcoming decommissioning work in Taiwan.

附錄五 設備廠商型錄

Argonne NATIONAL LABORATORY

BENEFITS AND FUTURE

ARG-US RFID enhances package safety, safeguards, and security (3S) with remote monitoring technology, resulting in efficient operations and cost savings.

- Continuous monitoring and tracking of package via sensors reduces exposure of personnel to radiation and the need for manned surveillance.
- Robust alert system transmits alarms instantaneously when any sensor threshold is violated.
- Coupled with patented ARG-US CommBox/CommBox-mini, the smart drum technology provides chain of custody and end-to-end coverage of risk-significant materials during transportation and storage.
- Future enhancements include a secured web application user interface, data analytics, geo-fencing, and linkage to Geographic Information Systems (GIS) database for emergency response and management.

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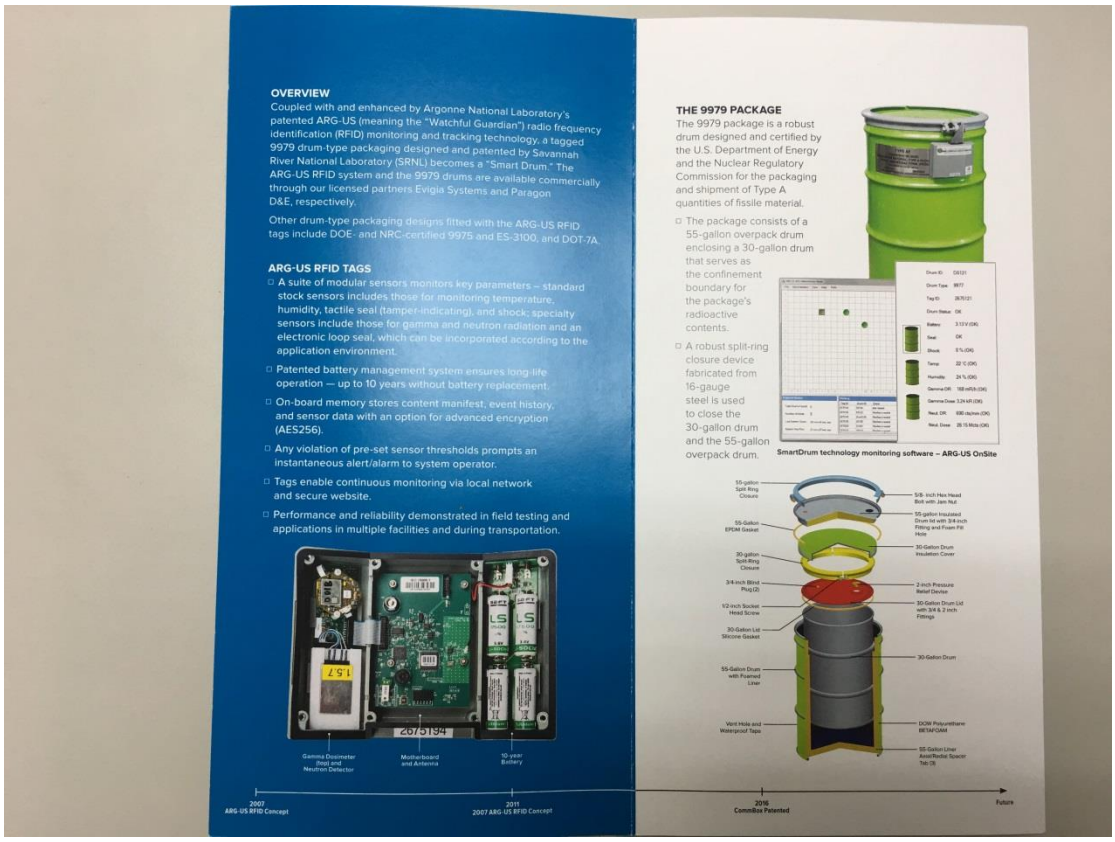
SMART DRUM TECHNOLOGY

ARG-US RFID Enhances Package Safety, Safeguards, and Security (3S) with Remote Monitoring Technology

Environmental Management — DOE PACKAGING CERTIFICATION PROGRAM

SRNL



OVERVIEW

Coupled with and enhanced by Argonne National Laboratory's patented ARG-US (meaning the "Watchful Guardian") radio frequency identification (RFID) monitoring and tracking technology, a tagged 9979 drum-type packaging designed and patented by Savannah River National Laboratory (SRNL) becomes a "Smart Drum." The ARG-US RFID system and the 9979 drums are available commercially through our licensed partners Evigia Systems and Paragon D&E, respectively.

Other drum-type packaging designs fitted with the ARG-US RFID tags include DOE- and NRC-certified 9975 and ES-3100, and DOT-7A.

ARG-US RFID TAGS

- A suite of modular sensors monitors key parameters – standard stock sensors includes those for monitoring temperature, humidity, tactile seal (tamper-indicating), and shock; specialty sensors include those for gamma and neutron radiation and an electronic loop seal, which can be incorporated according to the application environment.
- Patented battery management system ensures long-life operation — up to 10 years without battery replacement.
- On-board memory stores content manifest, event history, and sensor data with an option for advanced encryption (AES256).
- Any violation of pre-set sensor thresholds prompts an instantaneous alert/alarm to system operator.
- Tags enable continuous monitoring via local network and secure website.
- Performance and reliability demonstrated in field testing and applications in multiple facilities and during transportation.

THE 9979 PACKAGE

The 9979 package is a robust drum designed and certified by the U.S. Department of Energy and the Nuclear Regulatory Commission for the packaging and shipment of Type A quantities of fissile material.

- The package consists of a 55-gallon overpack drum enclosing a 30-gallon drum that serves as the confinement boundary for the package's radioactive contents.
- A robust split-ring closure device fabricated from 16-gauge steel is used to close the 30-gallon drum and the 55-gallon overpack drum.

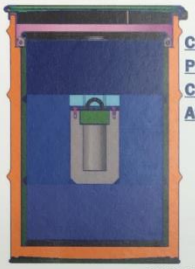
SmartDrum technology monitoring software – ARG-US OnSite


NRC & DOE Certified
9979-AF Shipping & Storage
Nuclear Waste Packaging
In Stock at
Paragon
Delivery
within
30 Days
• Listed on RAMPAC—Item 9979 AF-96
• Meets NQA-1
• Compact Size—55 Gallon Drum Footprint
• 30 Gallon Payload Container
Paragon
D&E
www.paragonde.com
info@paragonde.com
616-949-2220

DOE 7A Type A Liquid Shipping Package

9979-AF

Paragon D&E



Custom Payload Configurations Available

Barrels Video

PARAGON DELIVERS 9979-AF

Paragon D&E has launched production of the new 9979-AF advanced nuclear shipping and storage package. First deliveries of these shipping packages began in January 2011. The Department of Energy's Savannah River National Laboratory (SRNL) engineering and quality teams have approved the package for shipments. The contents to be shipped in the 9979-AF packaging includes radioactive (fissile and non-fissile) materials. The package includes a separate 30-gallon payload container that holds the actual fissile payload. The package can handle contents up to 200 pounds. Certification pending for payload weights up to 350lbs. SRNL and Paragon D&E worked together to design, test, and manufacture this advanced nuclear waste package over the last two years.

BEST IN CLASS

- Small footprint for shipping and storage of package
- All combustible AF waste material can be shipping in the 9979 shipping package
- Shipping package without payload- only weighs 220lbs.
- Patent pending, custom lined shipping package accepts a sealed 30-gallon payload container
- Reusable Option: once the 30 gallon payload container is unloaded, the 9979 shipping package may be reused for other shipments
- 30-gallon payload container is small and compact, resulting in easy loading and unloading of payloads in laboratory settings.

www.paragonde.com ■ info@paragonde.com

616-949-2220

6 DRUM OVERPACK (Pallet Style)

Volume:	6 - 55 gallon drums
Size I.D.:	79"L x 52"W x 41"H
Payload:	9,000/lbs.
Closure:	Bolted
Construction:	Carbon Steel

DOT tested for fissile material with a 6,000/lb. payload.

COMPACTOR BOXES

Volume: 90 cubic feet

Each container has a built-in anti-springback device. When used with the CPC "B-1000" compactor, a volume reduction 7 to 1 can be achieved on waste material.

B-25 OVERPACK

These containers are needed when a standa waste box has been breached and transportation containment is required. The container will be built to meet your payload requirements. Many payloads available.

CPC

CONTAINER PRODUCTS CORPORATION
112 North College Road, P.O. Box 3767, Wilmington, NC 28406
Tel: (910) 392-6100 Fax: (910) 392-6778
Web Page: http://c-p-c.com
E-mail: sales@c-p-c.com

B-25 WASTE CONTAINERS

Volume:	90 cubic feet
Size I.D.:	72"L X 46"W X 47"H
Payload:	6,000 to 40,000/lbs.
Closure:	"Seal Loc" Clips, Bolts, "T"-bolts, Latches
Construction:	Carbon Steel, Aluminum Stainless Steel

B-12 WASTE CONTAINERS

Volume:	45 cubic feet
Size I.D.:	72"L x 46"W x 23"H
Payload:	6,000 to 40,000/lbs.
Closure:	"Seal Loc" Clips, Bolts, "T"-bolts, Latches
Construction:	Carbon Steel, Aluminum Stainless Steel

6-DRUM OVERPACK (Standard)

Volume:	6 - 55 gallon drums
Size I.D.:	76"L x 52"W x 38"H
Payload:	8,000/lbs.
Closure:	"Seal Loc" Clips, Bolted, "T"-bolts, Latches
Construction:	Carbon Steel, Aluminum Stainless Steel

CPC

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112 North College Road, P.O. Box 3767, Wilmington, NC 28406
Tel: (910) 392-6100 Fax: (910) 392-6778
Web Page: http://c-p-c.com
E-mail: sales@c-p-c.com

B-36 CONTAINER

I.D.: 420"L X 44"W X 44"H
Payload: 30,000/lbs.

RPB CONTAINER

I.D.: 84"L X 84"W X 72"H
Payload: 20,000/lbs.

CPC
CONTAINER PRODUCTS CORPORATION

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Web Page: http://www.c-p-c.com E-mail: sales@c-p-c.com

HI-Q ENVIRONMENTAL PRODUCTS COMPANY, INC.
Air Sampling & Radiation Monitoring Equipment, Systems & Accessories

VF

Decontamination – Decommissioning – Radwaste

PRODUCTS & SERVICES

HI-Q Environmental Products Company is pleased to announce an expanded product portfolio that includes specialized instrumentation and services to satisfy the requirements for decontamination, decommissioning, and radwaste processing and storage. Hi-Q is now an exclusive partner with VF Company, an International expert in the design and manufacturing of instrumentation for the nuclear industry. HI-Q, an ISO 9001:2015 certified designer and manufacturer has been providing air sampling & monitoring systems and services to both nuclear and environmental clients since 1973. VF supplies a wide range of specialized Decon/Decom/Radwaste products and services and has continuously grown since 1992. Included are both individual radiation detectors and monitors either independently or as part of complete radiation monitoring systems. Specialized products and services include:

- **Waste Assay Monitors**
- **Radwaste Information Systems**
- **Decontamination/Waste Treatment Systems**
- **Radiological Monitoring Systems**
- **Conveyor (Manual, Semi or Auto. Loading)**
- **Hot Cell (Design & Construction)**
- **Small Item Monitors**
- **Perimeter Monitoring Systems (Wired/Wireless)**
- **Automatic or Mobile Stations (Dose Rate, Continuous Particulate, High Volume Air Samplers)**
- **Continuous Duty, Constant Flow Air Sampling Systems**
- **Filter Media for Air Sampling**
- **"All-In-One" Digital Air Flow Calibrators**
- **Adapters and Calibration Services**

WAM 200/300 series Waste Assay Monitors

"Waste-Scan" WAM-200 series monitors (such as our WAM-202 shown on the right) are used for spectrometric characterization of radioactive waste. They can be used in nuclear power plants, waste repositories, science facilities, reprocessing plants etc. for typically LLW/ILW measurements or free release (in Europe). Pictured above is the VF "Waste-Scan" WAM-300 monitor that is used for spectrometric characterization of radioactive waste and can be used in nuclear power plants, waste repositories, science facilities, reprocessing plants for typically LLW/ILW measurements.

More details on any of the VF or HI-Q products to meet site-specific requirements can be provided and we encourage you to visit: www.Hi-Q.net or www.VF.eu for more specifics or simply call the number below.

7386 Trade Street / San Diego, CA 92121 / Phone 858-549-2820 / Fax 858-549-9657 / www.HI-Q.net