參、心　得

於 ATL 期間：到 ATL 公司學習廢棄物管理及污染廢土處理之公差安排共約兩個月，期間都待在該公司蒐集相關資料並與相關廠商聯絡，因人出差在美國，所以接洽廠商方面較爲方便，而廠商也較願意與我方聯絡，如果距離允許的話還可以當面討論，但是許多美國廠商都是非常大的管理或是顧問公司，如果沒有認識的廠商推薦聯繫的話，信件都是石沈大海、音訊全無，且很多透過網路或是文獻收集到的廠商皆已更改名字、與他家公司合併或甚至倒閉，需要花相當多時間搜尋才可找到其聯絡資料。ATL 公司也有分析實驗室在 Hanford Site 內，但是因爲礙於安全因素，美方並不提供進入之許可，因此也無法到現場見識其規模與運作情形，實爲可惜，這方面還有賴核研所努力的地方，平常應多與國家級的實驗室接觸並做資訊的交流，最好每年都有互動及交流，如此才可能與其建立良好的關係，並學習到我方尙缺乏的技術。多與國外廠商接觸，可以增加國際視野，也比較不會被國內廠商牽著鼻子走，許多儀器之操作獲故障排除可以自行解決，不僅節省經費，也可增加相關經驗，會於意想不到的地方派上用場。而有關放射性廢土處理部分，礙於美國能源部已經將此部分的計畫停止，因此很多文獻上的公司都已經倒閉或是被合併，當時的負責人都聯絡不上，因此沒有辦法更廣泛的獲取更多資料，而與廠商會面及討論的結果，目前核研所可採用的廢土處理方法應是朝清洗的方向進行，因台灣小且人口密集，無法像美國使用掩埋的方式處理大量的放射性廢土，且污染土壤貯存於核研所內的總量相對美國也不算多，因此應趕緊成立計畫著手處理。

到 NRC 及 DC：與廠商實際見面並討論該公司發展之技術及處理經驗比透過電話或 email 收穫更多，除了面對面有更多的時間外，

語言溝通透過肢體等動作可以幫助英語能力上的不足造成的理解力下降，更可以與廠商建立良好的商場及友誼關係；到 NRC 與官員討論核能相關法規之問題受益良多，但是礙於本人涉足核能領域不深，且在交談中對方用了許多縮寫之專有名詞，因此對於問題之回答只能有表面的瞭解，更深入或其他相關的部分則不易理解，實在可惜！需加強核能法規方面的認識及探討才有辦法收穫更多。

生活上：很高興有機會可以到國外見識，雖然時間不長，但足以讓從未到過美國的人震撼不已，光是生活方式的差異就足以讓人花不少時間適應，加上語言理解上的差異，著實讓剛到美國的我震撼不已，心想學了一二十年的英文也不過爾爾，只能勉強溝通而已！利用空檔做的旅行更是大開眼界，美國如此之大不是台灣可以比擬的，不同的城市各自擁有不同的特色，停留一兩天只是對該城市特色淺嚐即止而已，還無法深入瞭解其形形色色的人、事、物，真的是讀萬卷書不如行萬里路！

肆、建議事項

放射性廢土處理技術在美國曾經是一個熱門的技術範疇，美國能源部及其所屬國家實驗室均投入眾多人力研究如何處理此一棘手問題，但至目前，我國投入的人力物力與其相比，實在是相差甚遠，因此核研所應趕緊成立計畫編列預算來執行放射性廢土的處理，才可得到自己的處理經驗及相對應的處理成效。

另外台灣的土地狹小，與美國的地理條件差異很大，因此美國採用的處理方法並不全盤適用於核研所，因此很多的調查資料只能當作評估性的參考，還是要以核研所的狀況來評估處理方法。

學習放射性土壤處理技術還是要以國家實驗室爲學習對象較爲恰當，但礙於美方的安全考量導致無法順利進入國家實驗室，實在甚爲可惜。

如果經費允許，將研習時間從 2 個月延長至 4 到 6 個月更可以增加學習的深度，包括整個設計概念及設備建造等都可以全盤瞭解。

對從沒到過國外的人來說，在國外生活是一件新鮮、刺激的挑戰，除了增廣見聞外，還會改變自己的人生看法，因此每年應多選送年輕人到國外實習。

伍、附　件

一、C&D Equipmemt 型錄

NEUENHAUSER SUPERSCREENER
Wheels – Tracks – 2 Way Split – 3 Way Split

C&D
EQUIPMENT
CRUSHING, SCREENING & RECYCLING EQUIPMENT

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352-861-6900 (VOICE) | 352-401-0405 (FAX)　WWW.AGGREGATEPROS.COM

PRODUCTION CAPABILITIES

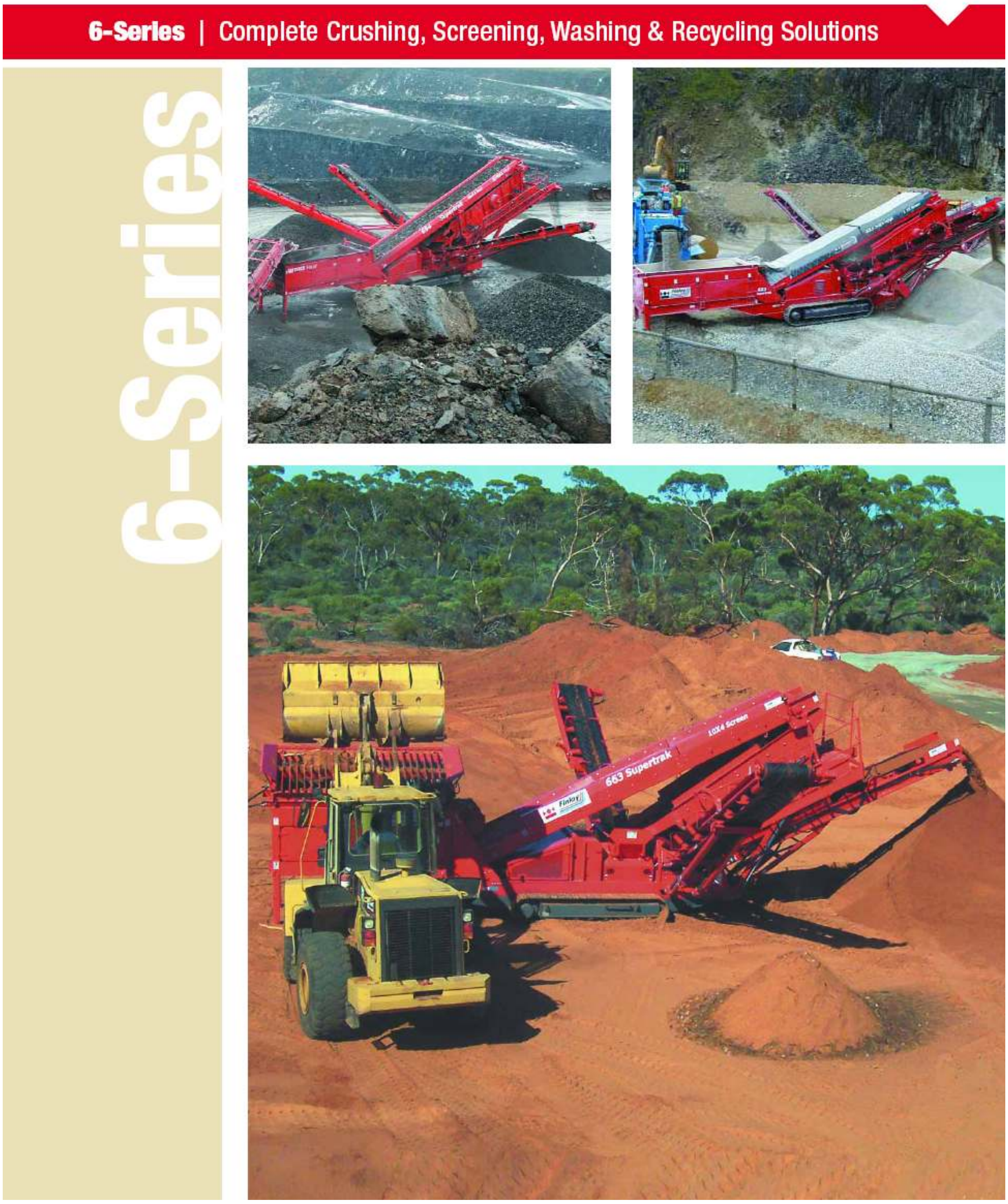
Limestone With Clay

PRODUCTION CAPABILITIES

Top Soil

二、Valley Equipment Company Inc.提供之土壤篩分設備明細

TEREX | FINLAY



6-Series | Complete Crushing, Screening, Washing & Recycling Solutions

6-Series

FINLAY 653

Tracked 3-way split screening unit designed to work in small processing yards and in more confined spaces. This fully self contained unit incorporates a direct feed system, enabling the 653 to work in line with mobile crushers. Standard features include a 3.05m x 1.25m (10' x 4') screenbox with full access walkway and three on-board hydraulic folding stockpiling conveyors.

Installation de criblage à 2 étages, sur chenilles pour la production de petits tonnages dans des environnements restreints. Cette installation autonome disposant d'une alimentation directe peut être alimentée en série avec un concasseur mobile. Crible de 3.05 x 1.25 m avec passerelles et 3 tapis de stockage rabattables hydrauliquement.

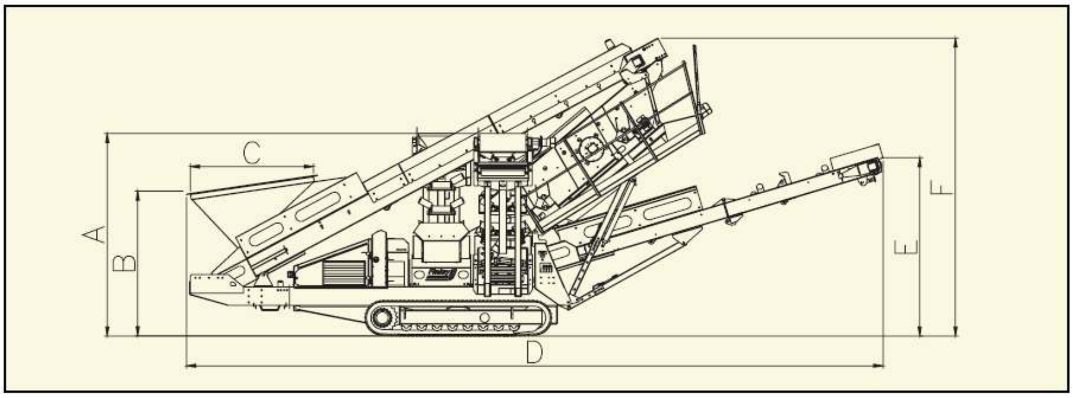
Raupenmobile 3-fach-Siebanlage für den Produzenten kleinerer Mengen und den Einsatz bei eingeschränkten Platzverhältnissen. Diese eigenständige Anlage verfügt über die Möglichkeit zur Direktaufgabe und kann so einem mobilen Brecher nachgeschaltet werden. Eine 3.05m x 1.25m (10' x 4') Siebmaschine mit Laufsteg und drei hydraulisch klappbaren Austragsbänder sind Standard bei dieser Anlage.

La Finlay 653 está montada sobre un chasis de orugas y ha sido diseñada para trabajar en zonas donde el espacio está limitado. Esta planta completamente autónoma, incorpora un sistema de alimentación directa para que pueda trabajar en cadena con grupos móviles de machaqueo. La 653 cuenta con una criba de 3.05 x 1.25 m completa con una pasarela y tres cintas transportadoras que se pliegan hidráulicamente.

Impianto di vagliatura a tre selezioni, cingolato, ideale per l'abbinamento ad un gruppo mobile di frantumazione, grazie all'alimentazione diretta. Elevata capacità produttiva nonostante le dimensioni compatte e possibilità di lavorare in spazi ristretti. Il vaglio a due piani e di dimensioni di 3,05 m x 1,25 m (10' x 4'), è dotato di ampia passerella su tre lati; completano la dotazione standard i tre nastri di scarico a ripiegamento idraulico, il telecomando per il carro cingolato ed i punti di ingrassaggio localizzati tutti a piano campagna. In opzione può essere equipaggiato di radiocomando per i cingoli e dei dispositivi idraulici per il tensionamento della rete del piano inferiore del vaglio e per l'inversione del senso di rotazione del vaglio.

653 Technical Specifications

Hopper Capacity	2.4m^3 (3.14yd^3)
Screen Size	3.05m x 1.25m (10' x 4') Top Deck
	2.35m x 1.25m (8' x 4') Bottom Deck
Engine	Deutz 51kw F4L914 Engine
Main Conveyor	800mm (32")
Side Conveyors	650mm (26") with Chevron belt
Fines Conveyor	1000mm (39")
Machine Weight	14 Tonnes (15.4 US Tons)



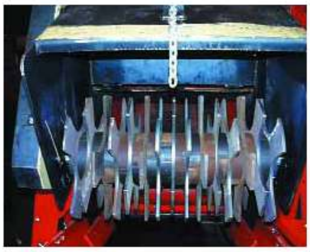
653

653 SUPERTRAK WORKING DIMENSIONS

A	B	C	D	E	F
3300mm (10' 10")	2460mm (8' 1")	2000mm (6' 7")	10950mm (35' 11")	3900mm (12' 10")	5000mm (15' 11")

653 SUPERTRAK TRANSPORT DIMENSIONS

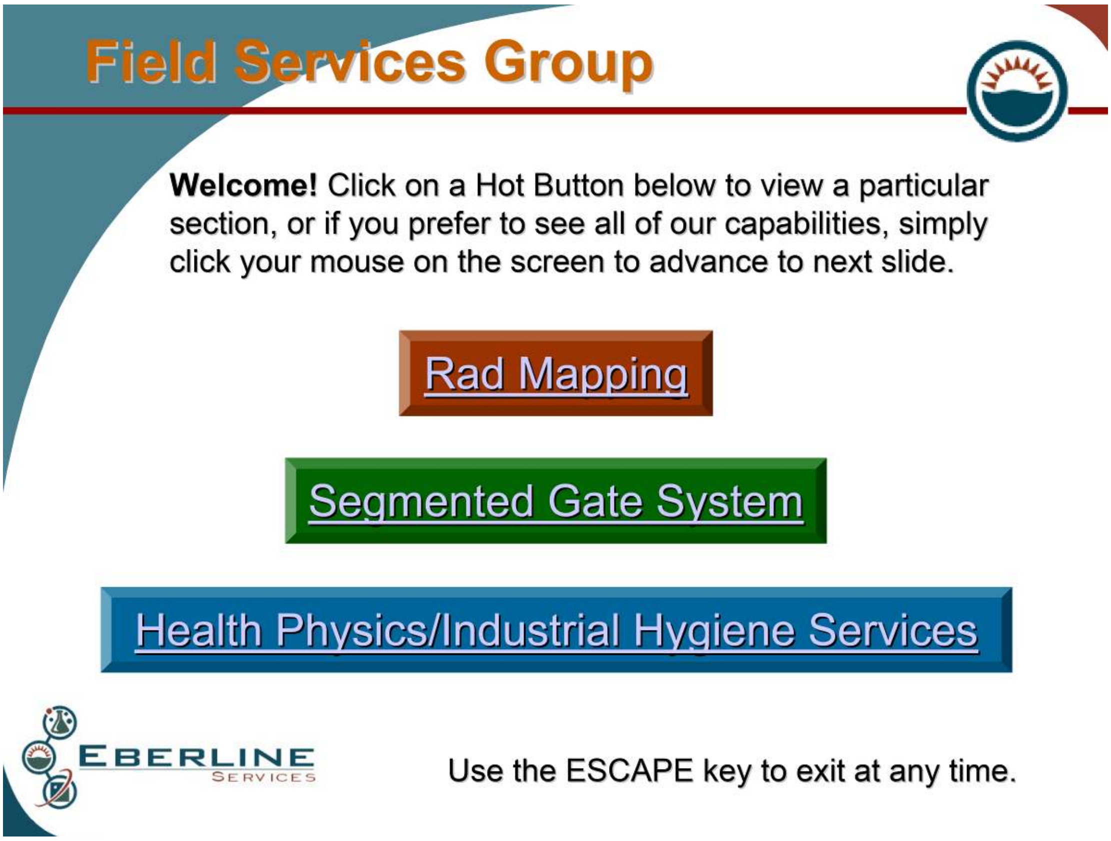
Length:	Width:	Height:
10.45m (34' 3")	2.75m (9')	3.32m (10' 11")




Finlay
694
Supertrak


Finlay
663 Supertrak

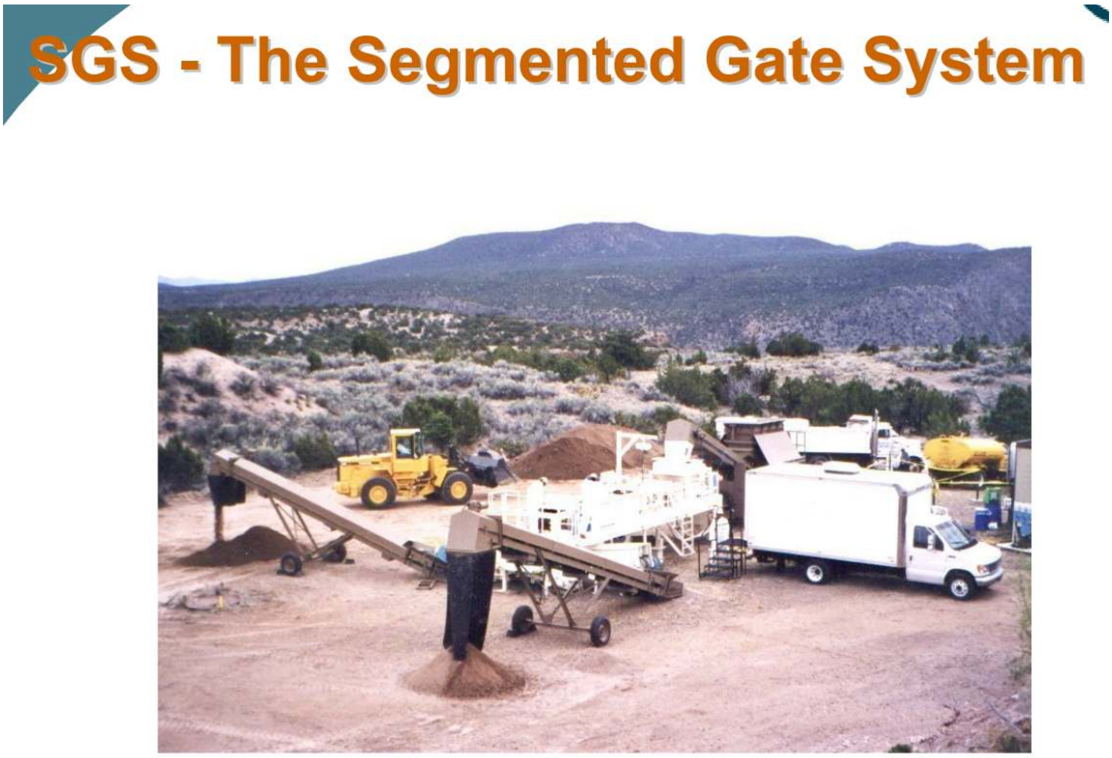
三、Eberline Services 提供有關 SGS 系統資料



Field Services Group

Welcome! Click on a Hot Button below to view a particular section, or if you prefer to see all of our capabilities, simply click your mouse on the screen to advance to next slide.

Use the ESCAPE key to exit at any time.



SGS - The Segmented Gate System

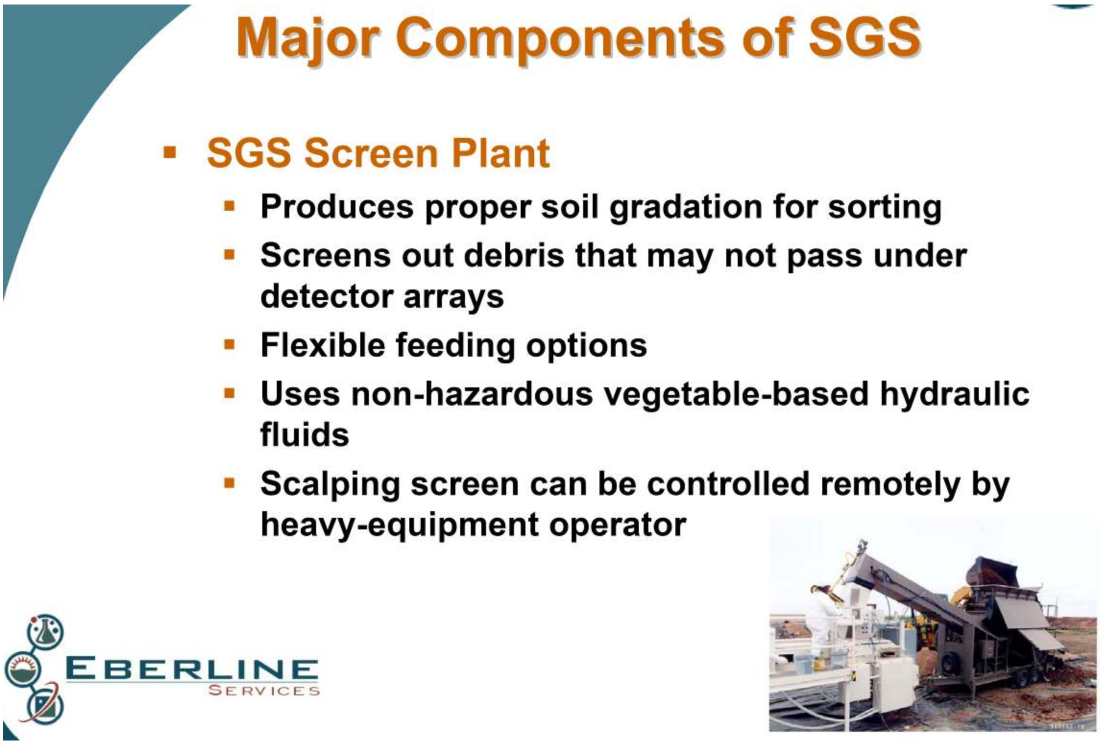
Segmented Gate System Features

- Cost-effectively reduces the volume of radioactive contamination in soil and other materials
- Sorts mechanically, making soil washing or chemical treatment unnecessary
- Provides an assay of 100 percent of all material processed
- Can operate on remote generator power or shore power
- Generates no secondary waste stream
- Simple, easy decontamination
- Rapid field calibration

Isotopes sorted:

- Cobalt 60
- Radium 226
- Cesium 137
- Thorium 232
- Uranium 238
- Americium 241

EBERLINE
SERVICES



Major Components of SGS

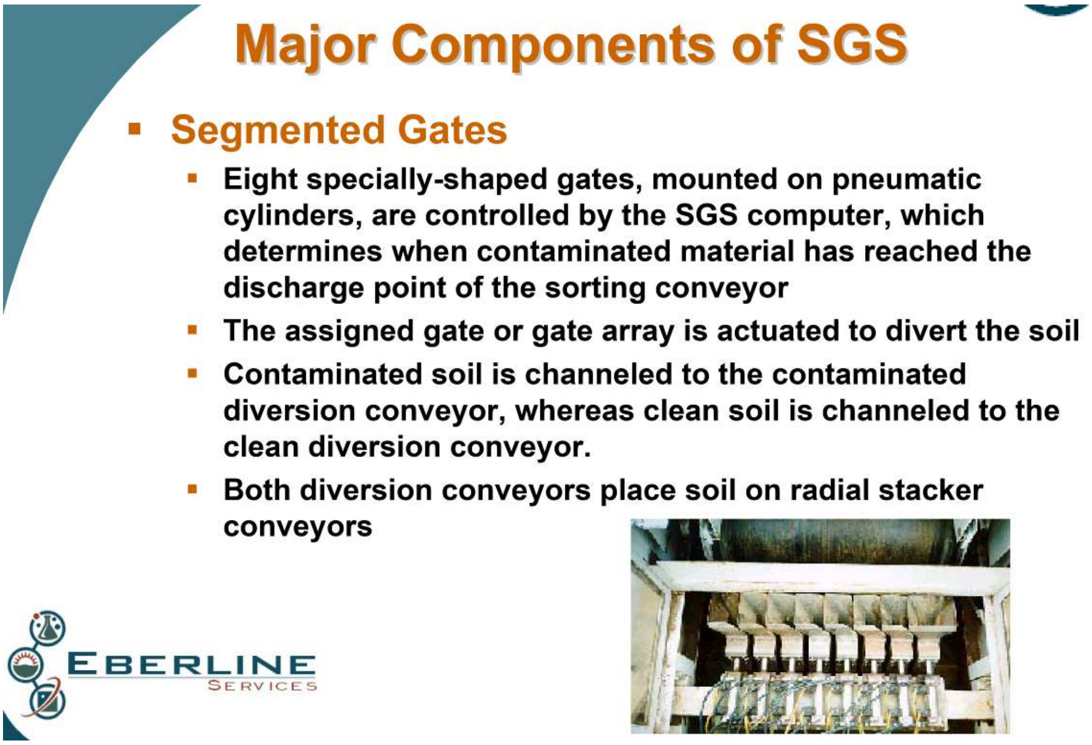
- SGS Screen Plant
  - Produces proper soil gradation for sorting
  - Screens out debris that may not pass under detector arrays
  - Flexible feeding options
  - Uses non-hazardous vegetable-based hydraulic fluids
  - Scalping screen can be controlled remotely by heavy-equipment operator

EBERLINE
SERVICES

EBERLINE
SERVICES

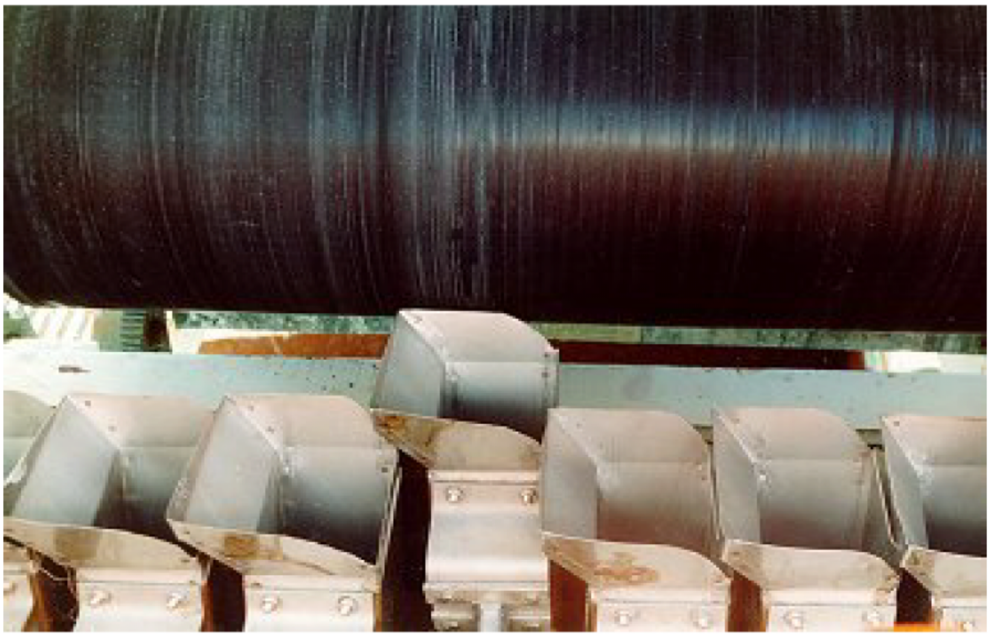
- **SGS Sorting Conveyor**
  - **Surge bin and speed controls for controlling non-uniform flow from screen plant**
  - **Integral adjustable screed controls thickness of soil stream deposited on conveyor**
  - **Heavily shielded dual NaI detector arrays for high and low energy photon detection**
  - **Adaptable to beta detection**

EBERLINE
SERVICES



Major Components of SGS

- Segmented Gates
  - Eight specially-shaped gates, mounted on pneumatic cylinders, are controlled by the SGS computer, which determines when contaminated material has reached the discharge point of the sorting conveyor
  - The assigned gate or gate array is actuated to divert the soil
  - Contaminated soil is channeled to the contaminated diversion conveyor, whereas clean soil is channeled to the clean diversion conveyor.
  - Both diversion conveyors place soil on radial stacker conveyors



Major Components of SGS

- SGS Radial Stacking Conveyors
  - One for clean soil; other for contaminated soil
  - Pivoting bases for radial pile creation
  - Deposit soil in piles or directly into containers or dump trucks

SGS Project Experience

Defense Threat Reduction Agency
Department of Defense

Los Alamos National Laboratory
Department of Energy

Bechtel National/ FUSRAP
Department of Energy

West Valley Site
Department of Energy

Sandia National Laboratory
Department of Energy

Nevada Test Site
Department of Energy

SGS Project Clients

Johnston Atoll, DTRA/DOD
Savannah River Site, DOE
Los Alamos National Laboratory, DOE
New Brunswick, NJ, FUSRAP/DOE
West Valley Site, DOE
Sandia National Laboratory, DOE
Pantex Plant, TX, DOE
Nevada Test Site/Tonopah Test Range, DOE
Ashtabula Site, DOE
Idaho National Engineering & Environmental Laboratory, DOE
Brookhaven National Laboratory, DOE
Maywood, NJ, FUSRAP/DOE
NPL Sites, Ottawa, IL, USEPA
Grefer Site, New Orleans, LA

See how the Segmented Gate System
can help your project. Contact us!

Bill Niemeyer

3200 George Washington Way, Richland, WA 99354
(509) 371-1506

601 Scarboro Road, Oak Ridge, TN 37830
(865) 291-8930

wniemeyer@eberlineservices.com

四、Perma-Fix Environmental Services 提供之 Segregation System 資料

The segregation system (Figure 1 through Figure 3) deployed combined gamma scanning (rolling detection; Figure 2) with gamma spectrometry, the two features of MARSSIM-based FSS. The conveyor counter utilized a fixed platform radiation detection system mounted over a rubber belt conveyor. The system contained two large-volume thallium-doped sodium iodide (NaI(Tl)) detectors housed in an environmentally controlled box for temperature stabilization and background radiation reduction. Gamma spectra in pre-defined energy ranges were collected successively over a fixed distance interval (122 cm) using a Multi-Channel Analyzer (MCA). The system was operated from an adjacent mobile trailer. The system included a controller for conveyor belt speed and sensors for conveyed material depth, detector temperatures, belt speed, and reversing belt direction.

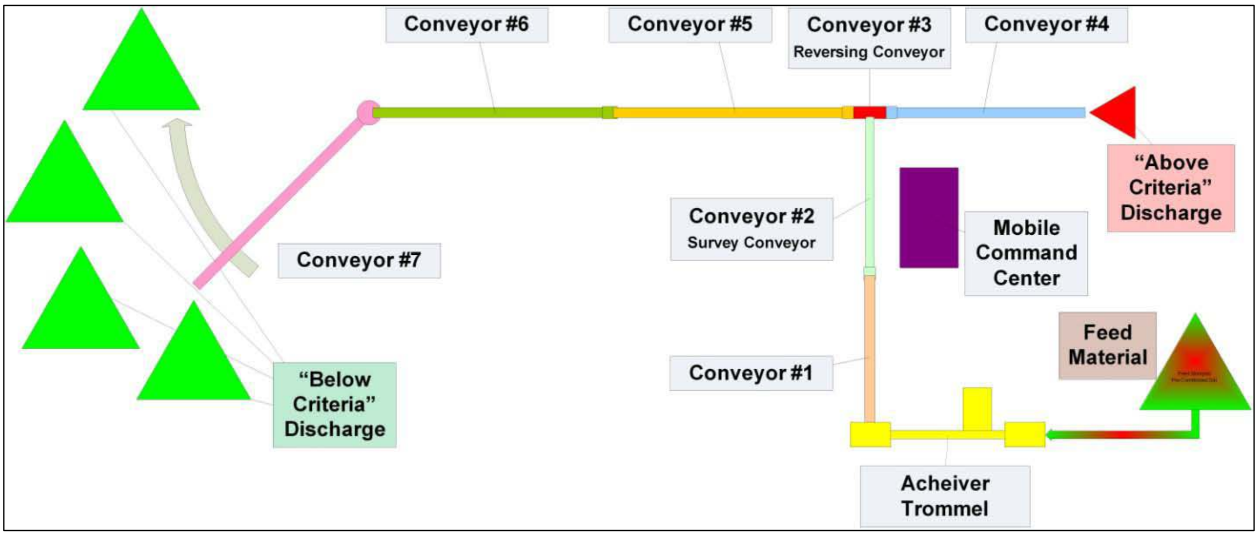


Figure 1 Layout of Soil Segregation System View A

Figure 2 Survey Conveyor and Environmentally Controlled Detector Box (White)

Calibration

Segregation system calibration to large volumes of soil with known elevated radioactivity concentrations is considered the most accurate method of calibration. Due to the lack of commercially available large volume calibration standards, volumes of soil standard material were collected from the site in areas with measureable Cs-137 activity. The soil volumes were prepared into calibration standards by homogenizing the material and assaying the radiological concentrations using the soil segregation systems' sodium Iodide (NaI) detectors, and by laboratory gamma spectroscopy analysis of a series of representative volumetric samples collected from each calibration reference standard. An unbroken chain of propagated errors tracing the calibration sources back to the National Institute of Standards and Technology (NIST) was established, making the sources NIST-traceable.

Operation of Soil Segregation System

Prior to assay by the soil segregation system, excavated material was pre-conditioned by drying (land farming) material and sizing it through a vibrating screen to remove debris over 10 cm (4 in) in diameter. The tilled and sized feed material was loaded by an excavator into the large hopper of an Achiever trommel. The rotating trommel drum provided a smooth and steady flow of soil material to the survey conveyor where material height was regulated by a "strike-off" bar which maintained a maximum belt fill depth of 15 cm (6 in). Depending on the operating conditions and data requirements, the material traveled at typical conveyor speeds between 30-70 cm/s beneath the suspended NaI detectors. The gamma spectrum was acquired for 122 cm of material, termed an "observation," and isotropically compared to the segregation criteria 0.192 Bq/g (5.2 pCi/g) Cs-137, half of the surrogate DCGL value for Cs-137, in real time. The position of each observation was automatically tracked by the segregation system as it travelled along the survey conveyor. Once the material reached the end of the survey belt, a proprietary reversing conveyor diverted the material to either the above or below criteria stockpiles depending on its volume-weighted average activity concentration.

The segregation system data is processed with algorithms similar to those developed for sonar. The algorithms greatly reduce the statistical fluctuation normally encountered in scanning detection. During each 122 cm observation (viewing approximately 79 kg (175 lb) of soil), the process computer records the spectra and live time from the multi-channel analyzer (MCA), the conveyor distance traveled, and the average height of the material. While these signals are collected and monitored during operations, the system offers real time, low-level radiation alarming functions based on data analysis.

Figure 3 Layout of Soil Segregation System View B

The segregation system data was used to calculate a weighted average activity concentration of the material in both the above and below criteria discharges. Material sent to the below criteria side was discharged into distinct batches and isolated until the confirmatory radiological soil sample measurements verified the segregation system's response. Batch pile size of a nominal 450 MT (500 tons) was implemented as an analogous volume to a MARSSIM Class 1 Survey Unit suggested maximum size [9].

QA/QC

In order to meet the QA/QC requirement to re-survey 5% of the material as required in the site final status survey plan (FSSP), another unique approach was required to minimize the cost and effort to fulfill such a requirement. Traditional approaches would have required the establishment of a laydown area where Radiation Protection Technicians (RPTs) could effectively hand-scan a 6" lift of the assayed material. Instead, an auxiliary detection system was configured and installed to monitor material discharged to the below criteria stockpile. The auxiliary system consisted of two large volume NaI detectors shielded and housed in environmentally controlled boxes similar to the soil segregation detectors. The auxiliary system operated on an identical version of software as the soil segregation system, using the same algorithms to perform real time density corrected gamma spectroscopy. The detectors, sensors, and support electronics were mounted on and around a transfer conveyor (Figure 4) carrying "below criteria" material to the backfill stockpile area (conveyor #6 in Figure 1), such that no additional material handling was required.

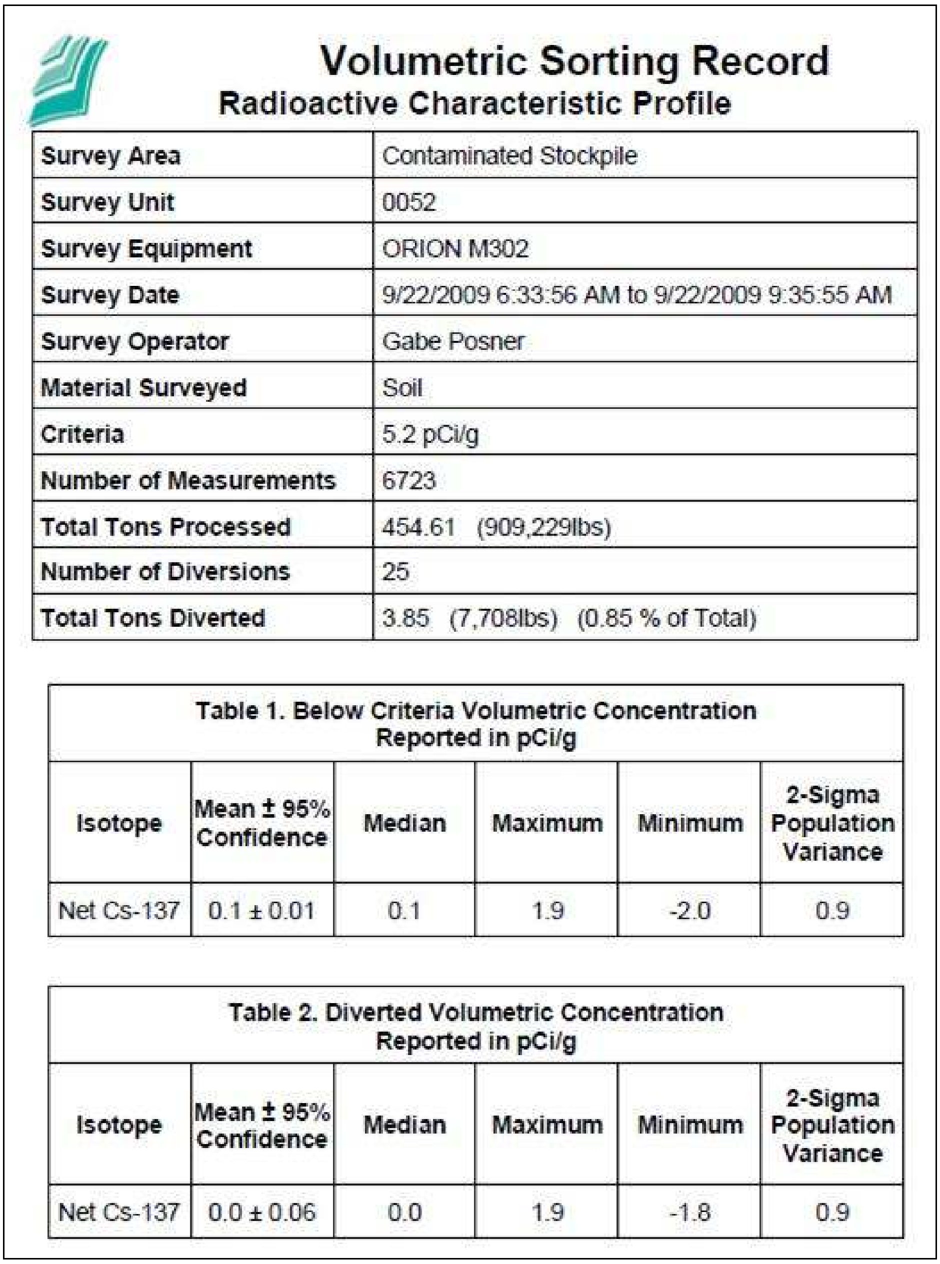
Additionally, confirmatory soil samples were collected throughout the project as part of the soil sorting project's internal quality process and FSS requirement. A radiation protection technician (RPT) collected a representative number of samples from each "below criteria" survey unit. Samples were submitted to the onsite radiological assay lab for analysis. Sample results from each survey unit were compared with the results generated by the soil segregation system's software.

Figure 4 Auxiliary QA/QC Detection System Mounted on Conveyor #6

Results

Over 88,000 MTs (97,000 tons) of material was sorted during the project. More than 1,636,000 measurements were taken by the segregation system, assaying 211 piles. The data indicates that the 211 piles assayed during the soil sorting campaign had an average Cs-137 concentration only slightly higher than background levels, with a maximum mean pile concentration of 0.0148 Bq/g (0.4 pCi/g). Table 1 lists the segregation system’s typical data processing output.

Table 1 Segregation System Batch Output Results



Volumetric Sorting Record

Radioactive Characteristic Profile

Survey Area	Contaminated Stockpile
Survey Unit	0052
Survey Equipment	ORION M302
Survey Date	9/22/2009 6:33:56 AM to 9/22/2009 9:35:55 AM
Survey Operator	Gabe Posner
Material Surveyed	Soil
Criteria	5.2 pCi/g
Number of Measurements	6723
Total Tons Processed	454.61 (909,229lbs)
Number of Diversions	25
Total Tons Diverted	3.85 (7,708lbs) (0.85 % of Total)

Table 1. Below Criteria Volumetric Concentration
Reported in pCi/g

Isotope	Mean ± 95% Confidence	Median	Maximum	Minimum	2-Sigma Population Variance
Net Cs-137	0.1 ± 0.01	0.1	1.9	-2.0	0.9

Table 2. Diverted Volumetric Concentration
Reported in pCi/g

Isotope	Mean ± 95% Confidence	Median	Maximum	Minimum	2-Sigma Population Variance
Net Cs-137	0.0 ± 0.06	0.0	1.9	-1.8	0.9

Note: Soil was also diverted for low density, i.e., if soil passing beneath the detectors was not of sufficient density to provide the appropriate counting geometry/statistics, the soil was diverted.

The auxiliary detection system re-assayed over 30,844 MTs (34,300 tons) of material, and collected 1,044,000 measurements. During its operation, the auxiliary system confirmed that no volumes of soil having a mass of 79 kg (175 lbs) or more and a Cs-137 concentration above 0.38 Bq/g (10.3 pCi/g) were discharged to the "below criteria" side. At the completion of the project the auxiliary system ensured compliance with the FSSP requirement of re-surveying at least 5% of the material by assaying over 35% of material.

The data population generated from the segregation system was further compared with the data population of the laboratory results generated from analyses of confirmatory samples of the below criteria pile. Figure 5 shows the results were remarkably consistent with regard to both precision and accuracy, having an average differential in reported means of approximately 0.0074 Bq/g (0.2 pCi/g).

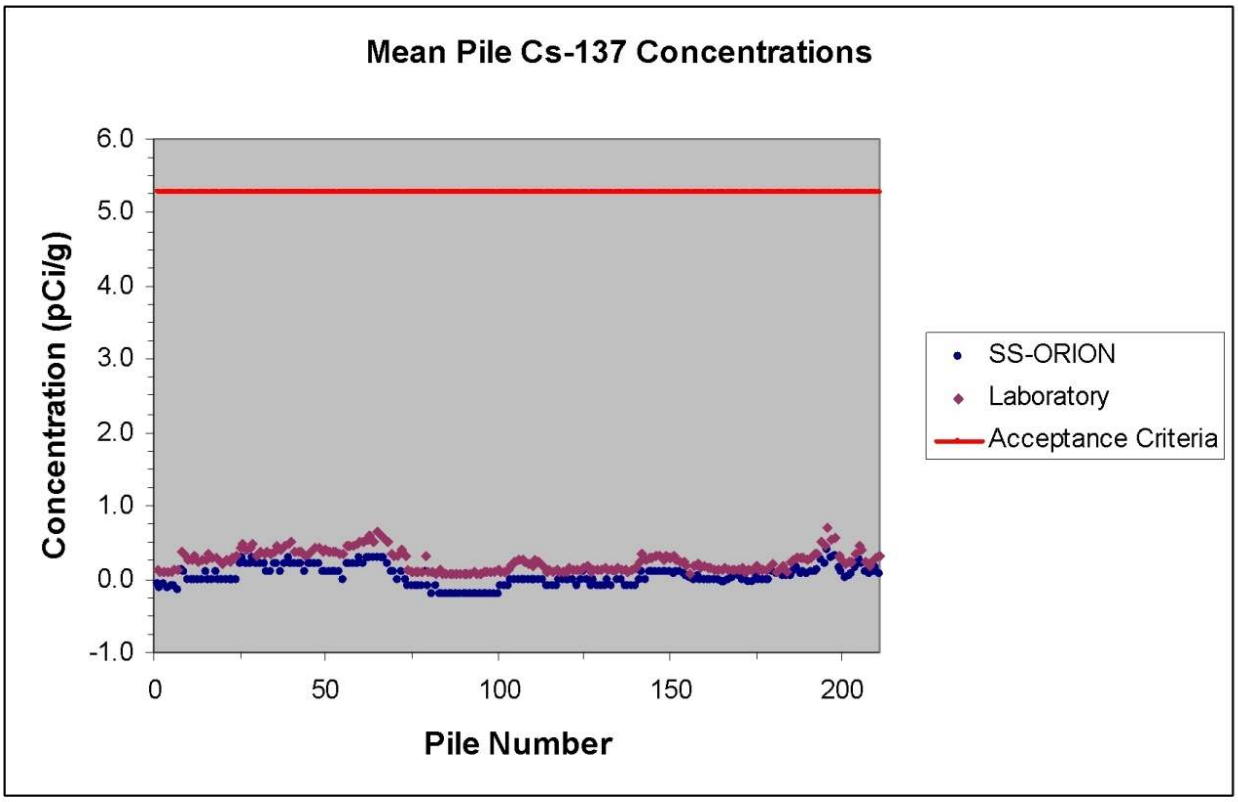
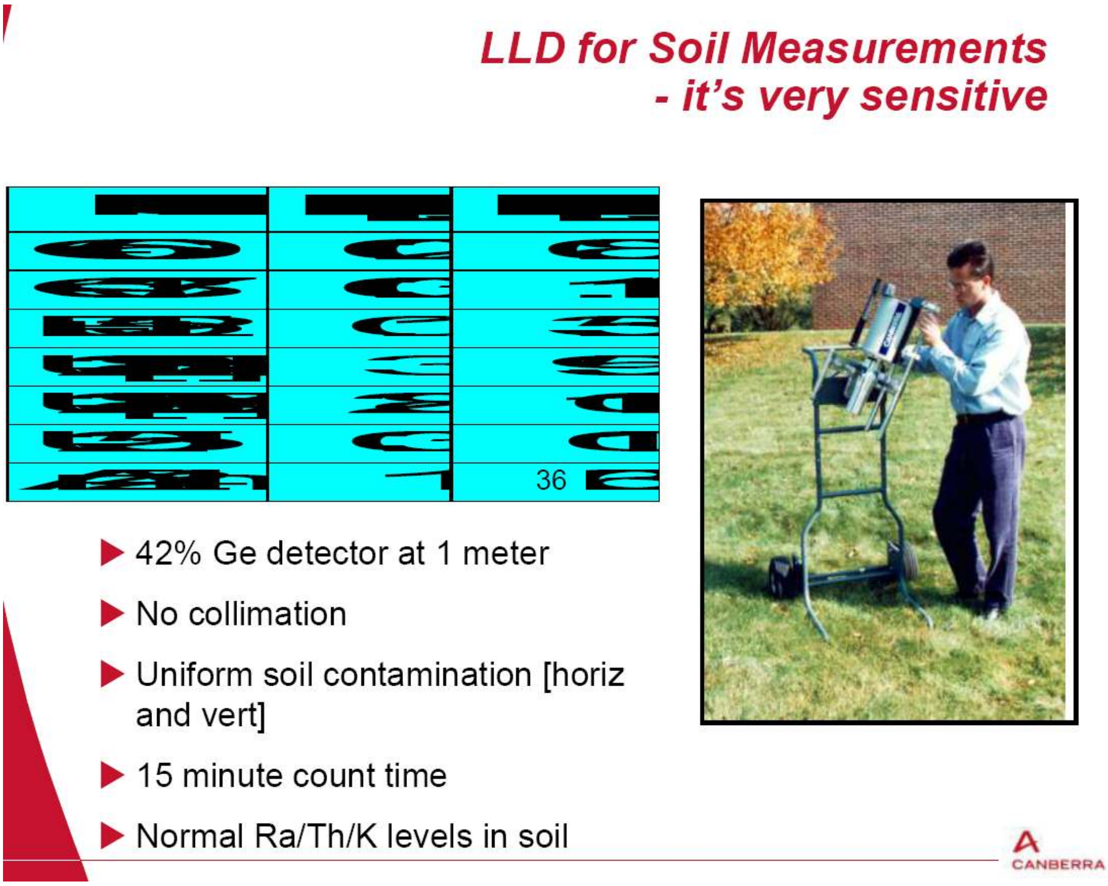


Figure 5 Comparison of Reported Mean Pile Cs-137 Concentrations

五、Canberra 公司之污染土壤偵測設備



LLD for Soil Measurements - it's very sensitive

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[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	36 [illegible]

- 42% Ge detector at 1 meter
- No collimation
- Uniform soil contamination [horiz and vert]
- 15 minute count time
- Normal Ra/Th/K levels in soil

CANBERRA

Systems applications
Calibrate any Ge detector for most any type of counter

- Gamma waste assay systems
- Liquid coolant/effluent monitoring systems
- Gaseous or Stack monitoring systems
- Post Accident Sampling Systems [PASS]

- Calibrations generally lower in cost and more accurate than source calibrations

Mounted on cherry picker for large area surveys
Big Rock Point NPP

Environmental box for large area measurements

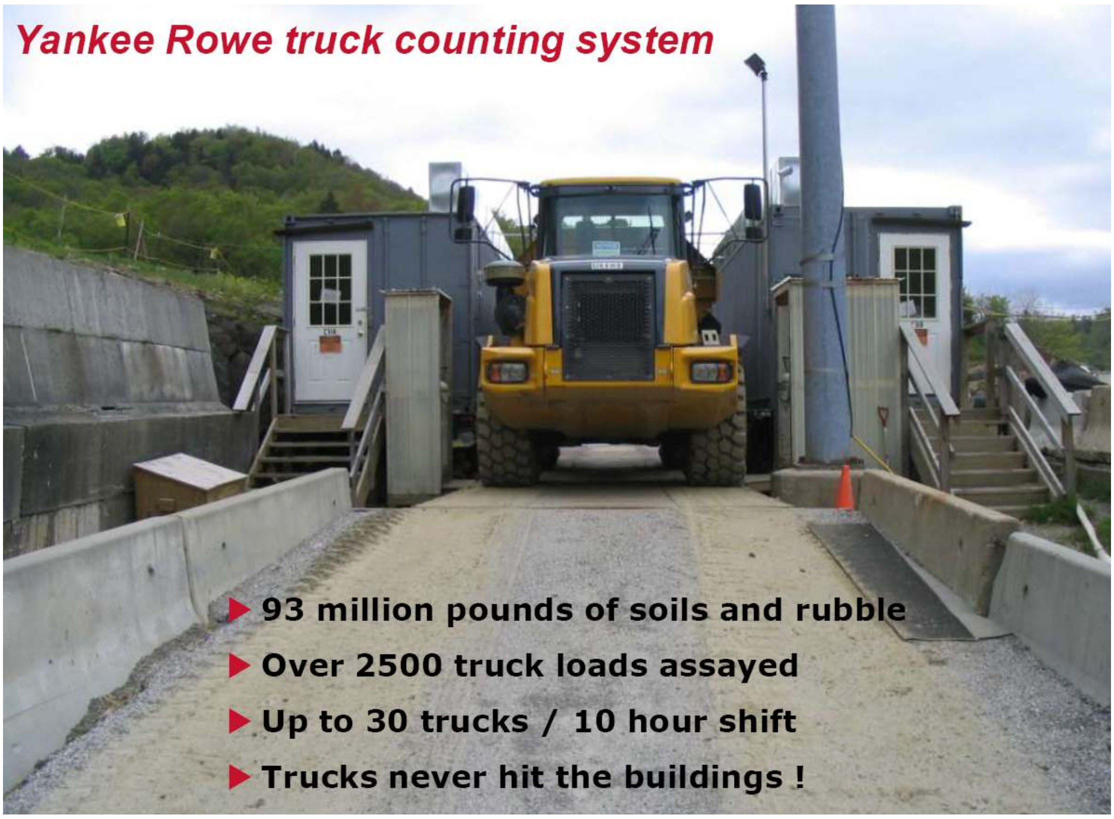
- Detector
- Collimator
- MCA
- Local computer
- Wireless modem
- Battery
- Remote control computer

CANBERRA

Truck counting station

Yankee Rowe courtesy Greg Austrauckus

- Truck screening station
- 6 Ge detectors [3/side]
- “Good” soil used as backfill on site
- Calibrated truckload using ISOCS
- Similar unit supplied to NFS



Yankee Rowe truck counting system

- 93 million pounds of soils and rubble
- Over 2500 truck loads assayed
- Up to 30 trucks / 10 hour shift
- Trucks never hit the buildings !

The Yankee Rowe Swinging ISOCS

CANBERRA

Box Segmented Gamma Scanner (BSGS)

Standard gamma box counting system.

- ISOCS used to calibrate standard Box counters
- NDA2000 used to allow automatic interpolation between multiple calibrations

六、Chesapeake Nuclear Services 公司提供之 CRATER 系統文獻摘錄

Edward Traverso, J. Stewart Bland, Paul R. Steinmeyer, “Screening Excavated Soils for Spent Fuel Fragments Using a Compton to Cs-137 Photopeak Ratio Methodology - 9525”, WM2009 Conference, USA

WM2009 Conference, March 1-5, 2009, Phoenix, AZ

Screening Excavated Soils for Spent Fuel Fragments Using a Compton to Cs-137 Photopeak Ratio Methodology - 9525

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ABSTRACT

Washington Closure Hanford LLC, working with Chesapeake Nuclear Services (ChesNuc), undertook a study to evaluate radiation detection instrumentation and possible methods that could be used for identifying the presence of Spent Nuclear Fuel (SNF) fragments during the excavation of the reactor burial trenches at the Hanford Reservation. The focus of the study was for a real-time capability with radiation detectors located on or around an excavator (and bucket), providing indication to an operator of radiation levels and potential for presence of a SNF fragment during the actual excavation process. The result was the development of an innovative gamma measurement and spectral analytical methodology to screen soils for potential spent fuel fragments. The screening methodology is based on the principle that for a specific radiation source (in this case a spent fuel fragment) as the depth (soil shielding) increases, the Compton scatter component of the spectra increases in ratio to the unattenuated photopeak intensity. Consequently, by examining spectral characteristics using gamma spectroscopy instrumentation and evaluating the Compton scatter component with the Cs-137 photopeak intensity, a determination can be made as to the potential for the presence of a spent fuel fragment. The methodology developed does not require knowledge of the depth of the spent fuel fragment in the soil column (i.e., excavator bucket).

INTRODUCTION

The remediation of the reactor burial trenches at the Hanford Reservation is a significant element of the overall Hanford clean-up activities. Buried in the trenches that are located adjacent the reactor sites are various rubble, components and miscellaneous materials that resulted from the decommissioning of the reactors. The significant, gamma-emitting radionuclides present in the reactor burial trenches are Co-60, an activation product mainly associated with reactor components, and Cs-137, a fission product and main constituent for a spent nuclear fuel (SNF) fragment.[1] The remediation activities require that spent fuel fragments be segregated and processed separately from the other remediated materials. Therefore, a method is needed for identifying these fuel fragments, which have been characterized as material containing greater than 1.1 Ci of Cs-137 from other Co-60 contaminated materials. The varying Co-60 radioactive component in the trenches renders the use of gross radiation measurements alone incapable of distinguishing between elevated levels associated with a potential SNF fragment versus that arising from increased Co-60 contamination. However, distinctions can be made by examining the gamma spectra characteristics associated with the Cs-137 (SNF fragment) and those for Co-60.

Field measurements were collected with several different type detectors with gamma spectral capabilities for an actual fuel fragment located at varying depths in a typical excavator bucket. Based on the results of this study, it was determined that NaI detectors provided sufficient spectral capabilities and were best

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[1] It has been approximately 30 years since the disposal of radioactively contaminated materials in the subject burial trenches. Therefore, through radioactive decay, most activation and fission products are no longer present. For gamma-emitting radionuclides, there is a relatively minor presence of Eu-152 with its 13.6 year half-life; but is insignificant compared with the presence of Cs-137 in a SNF fragment.

suited for the burial trench excavation environmental conditions. Initial field testing of a prototype system was conducted in early 2008. In September 2008, additional field acceptance testing was conducted at the 100-D complex using an actual SNF fragment attached to the bottom of an excavator bucket that had been modified with the bucket depth limited to 76 cm (30 inches) to be consistent with the bounds of the modeling and detection of a SNF fragment.

Based on the results of the study and subsequent field testing, an innovative gamma measurement and spectral analytical methodology was developed to screen soils for potential spent fuel fragments. The screening methodology is based on the principle that for a specific radiation source (in this case a spent fuel fragment with greater than 4.1E+10 Bq (1.1 Ci) of Cs-137) as the depth (soil shielding) increases, the Compton scatter component of the spectra increases in ratio to the unattenuated photopeak intensity. Consequently, by examining spectral characteristics using gamma spectroscopy instrumentation and evaluating the Compton scatter component with the Cs-137 photopeak intensity, a determination can be made as to the potential for the presence of a spent fuel fragment. The methodology developed does not require knowledge of the depth of the spent fuel fragment in the soil column (i.e., excavator bucket). This same methodology can also be applied for the screening for high dose rate items, such as a Co-60 source, that could pose a DOT transportation concern.

The result of this effort was the development of a specialized radiation detection system called ***CRATER™*** (Compton Ratio Analysis for Testing Environmental Radioactivity) and its proprietary software application ***CoRE*** (Compton-Ratio Evaluation) for screening excavator bucket soil content for presence of a spent fuel fragment. The screening methodology is based on conservatively established threshold conditions as a real-time means for clearing excavator bucket content. Application of the ***CRATER™*** for burial trench remediation activities will improve operations by providing a real-time screening of excavator buckets for SNF fragments and reduce personnel exposures by minimizing hands-on surveys of trench excavated materials.

SYSTEM DESCRIPTION

CRATER™ is enclosed in an aluminum housing, which is affixed to the arm of an excavator boom. The outside dimensions can be described as a solid right triangle "wedge" with 41 cm (16 inches) sides and 36 cm (14 inches) width. It is positioned such that the bottoms of the detectors are a nominal 61 cm (24 inches) from the top of the bucket/soil. The detector housing is constructed primarily of 0.6 cm (0.25inches) aluminum with a detector window of reinforced low-Z material to provide an essentially open field of view for the detectors to the excavator bucket.

Within the housing are two NaI(Tl) detectors. One is a 1-inch diameter by 1-inch long crystal intended for low-range operation of less than 0.2 mSv/h (<20 mR/h). The other is a 0.25-inch diameter by 1-inch long crystal intended for high-range operation for greater than 0.2 mSv/h to 3.5 mSv/h (>0.2 mSv/h to <350 mR/h). Positioned between these two detectors is an energy-compensated "peanut" G-M tube, which provides the ambient gamma radiation exposure rate as used by the system for determining which detector to use for the screening. This G-M provides indication of radiation levels exceeding the established system operating limit). Also housed within the wedge are two modified multi-channel analyzers (one for each NaI(Tl) detector); a motorized assembly for placing a gain-stabilization source in proximity to the detectors and retracting it back to a shield; and a master controller board responsible for direct management of all functions within the wedge and communication with the external controlling device.

CRATER™ is controlled via a master controller board communicating via Bluetooth with a Trimble RECON (a ruggedized PDA running the Windows Mobile 6 operating system). The software application residing on this RECON provides the user interface for controlling system operations, such as to begin measurements, evaluate spectrum for potential fuel fragment (utilizing the application methodology).

Other functions, such as daily source checks, backgrounds and save/retrieve/view past spectra, are also controlled via the RECON.

Customized Multi-Channel Analyzer Description

The ***CRATER™*** contains two multichannel analyzers (MCA) for acquiring spectra from the two scintillation detectors. These MCAs are customized systems that have been specifically designed for the collection and analysis of the measurements as required for this project. They have been adapted to operate using raw excavator power (9 to 36 volts DC) and to minimize the heat generated by the electronics. Additionally, a specialized internal microcontroller has been included with expanded memory and processing capability to handle the real-time processing of spectral data on a continual basis. The microcontroller firmware has been adapted to support a more efficient data packet to ensure integrity of transmitted spectra, improved autonomous operation, high precision acquisition timing, and initialization without the intervention of an external controlling device. Hardware settings (high voltage, threshold, gain, and fine gain) are maintained in the non-volatile memory and the last-used settings are re-loaded on power-up. Regions of interest (ROIs) were established for analyzing the spectra. ROIs for the 0.667 MeV Cs-137 photopeak, the Cs-137 Compton continuum, and the 1.17 and 1.33 MeV Co-60 photopeaks, as described later.

Computer Application Description

The computer software program for the ***CRATER™*** running on the RECON was written specifically for this application using embedded Visual C++ version 4.0. The application provides control signals to the system, retrieves data from the MCAs and other sensors, and performs the Compton-Ratio Evaluation (***CoRE***) proprietary software application for screening excavator bucket soil content for presence of a SNF fragment. Additionally, the application controls the operation of the gain stabilization routine, background measurements, and continual QA/QC checks for ensuring proper system operation. The automated fine gain adjustment initiates check source measurements for all three detectors (two NaI(Tl) scintillation detectors and one G-M detector). Spectra are acquired and, as required, the fine gain is automatically adjusted to align the 662 keV peak with MCA channel 110, which has been established as a standard design feature to support multiple systems operations, exchange, maintenance, and comparison. This operation also provides a source check for the detectors. As a QA measure, all three detectors are required to have background-subtracted total counts within 20% of that determined during calibration.

Dose Rate Operating Bounds and Energy Shift

NaI(Tl) detectors are highly efficient at detecting gamma photons. This characteristic also limits the upper range of the detectors, since each pulse requires a finite amount of time for the MCA to process. As pulses (or count) exceed 30,000 per second, the ability of the MCA to differentiate between pulses becomes limited until such time as no useable pulse height data can be extracted. To address this limitation, the ***CRATER™System*** uses two detector/MCA systems – a 1X1 inch detector for low ambient dose rate conditions and a smaller 0.25X1 inch detector for higher ambient dose rate conditions.

Measurements were performed at RSA's calibration laboratory in Hebron, CT, for the purpose of evaluating performance for the 1X1 inch and 0.25X1 inch NaI(Tl) detectors. The detectors were subjected to a 3.7E+09 Bq (100 mCi) Cs-137 source with measurements taken at numerous distances for a variety of photon fluence rates and corresponding dose rates. Figures 1 and 2 present spectral measurements for the 1X1 and 0.25X1 inch detectors, respectively. As Figure 1 shows, the 0.36 and 0.32 mSv/h spectra show an uncharacteristic feature (spike) around 90 keV, while the 0.20 and 0.14 mSv/h spectra have the more typical spectra distribution. Likewise, Figure 2 shows that for the 0.25X1 inch detector, a saturation condition occurs for the 5.1 mSv/h spectrum, while the 3.6 mSv/h spectrum shows typical distribution.

Based on these measurements, the 1X1 inch NaI(Tl) detector provides a useful operating range up to about 0.20 mSv/h, which has been established as its maximum operable exposure rate for this application. The 0.25X1 inch NaI(Tl) detector has an upper operating limit around 3.5 mSv/h.

七、Chesapeake Nuclear Services 之 CRANTER 系統簡介及開發過程

U.S. Department of Energy
Richland Operations Office

CRATER

Screening Excavated Soils for Spent Fuel Fragments Using a Compton to Cs-137 Photopeak Ratio Methodology

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November 2011

Chesapeake Nuclear Services

Issue – Spent Nuclear Fuel (SNF) Fragments in the Burial Trenches at Hanford

- Cross Functional / Cross Project Team –
  - Remediation Project Management / Project Engineering
  - Waste Operations
  - Waste Services
  - Radiation Safety / Health and Safety
  - Environmental Compliance
- Charter – Identify way to identify and remediate spent fuel fragments from burial trenches more efficiently.

Chesapeake Nuclear Services

Technology Selection

- Chesapeake Nuclear Services tasked with evaluating methodologies (detection and analysis).
- Gamma spectroscopy instrumentation coupled with unique spectral analytical techniques.
- Established success criteria
  - Equipment mounted real-time monitoring
  - Function reliably in the operational environment
  - Meet required detection requirements. Equivalent to current SNF discovery process
  - Minimizes worker exposure and improves ALARA

SNF Discovery Optimization Development Approach

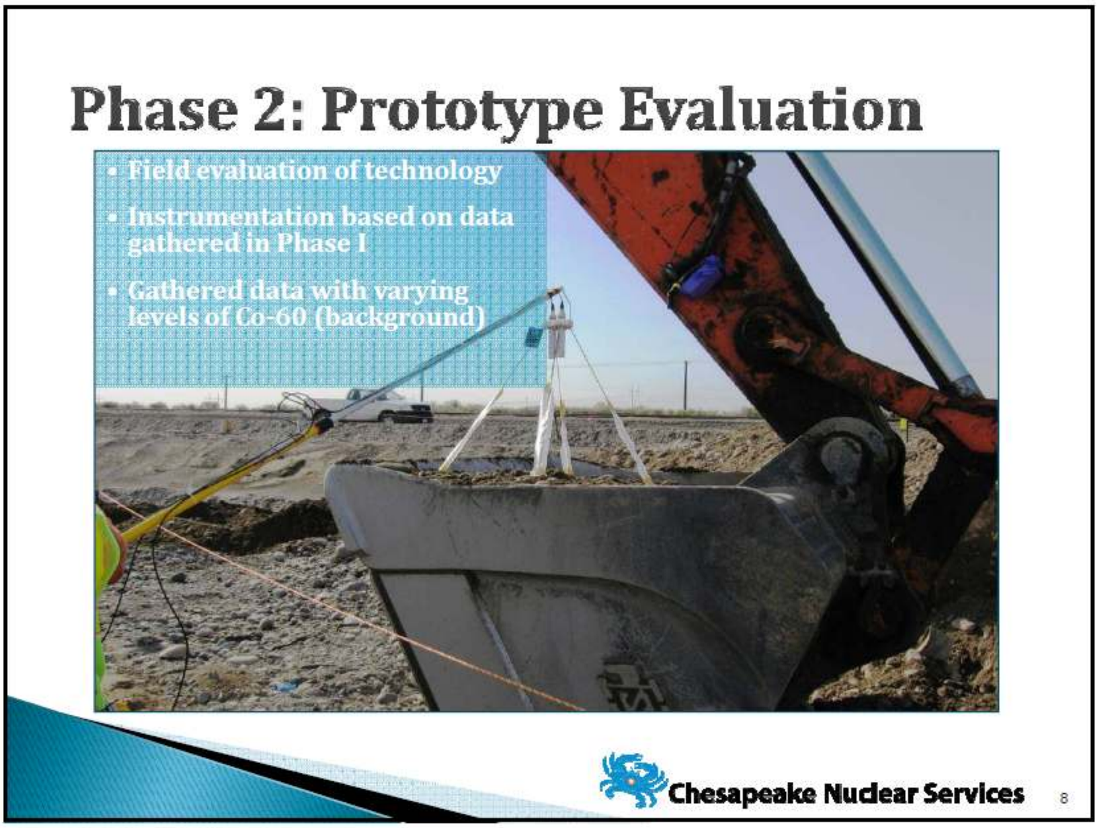
- Work performed in 5 Phases:
  - Phase 1: Proof of Concept
  - Phase 2: Prototype Evaluation
  - Phase 3: Final Design/Layout and Operation Considerations
  - Phase 4: Demonstration Testing
  - Phase 5: Improvements in Design and Operation
- Data collected from each phase provided the foundation for the next phase.
- Cross-functional/project collaboration throughout

Reactor Component Burial Trench

Refuel and Repair Debris

- Valves
- Spacers
- Piping

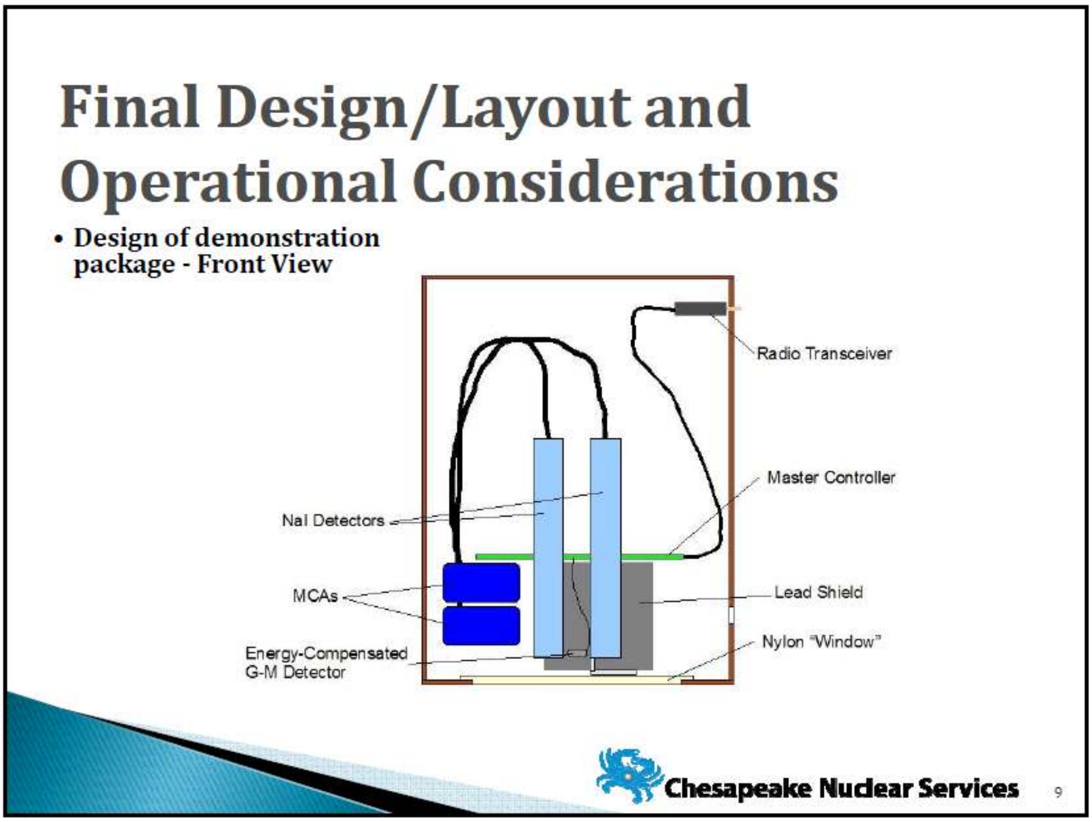
Phase 1: Proof of Concept



Phase 2: Prototype Evaluation

- Field evaluation of technology
- Instrumentation based on data gathered in Phase I
- Gathered data with varying levels of Co-60 (background)

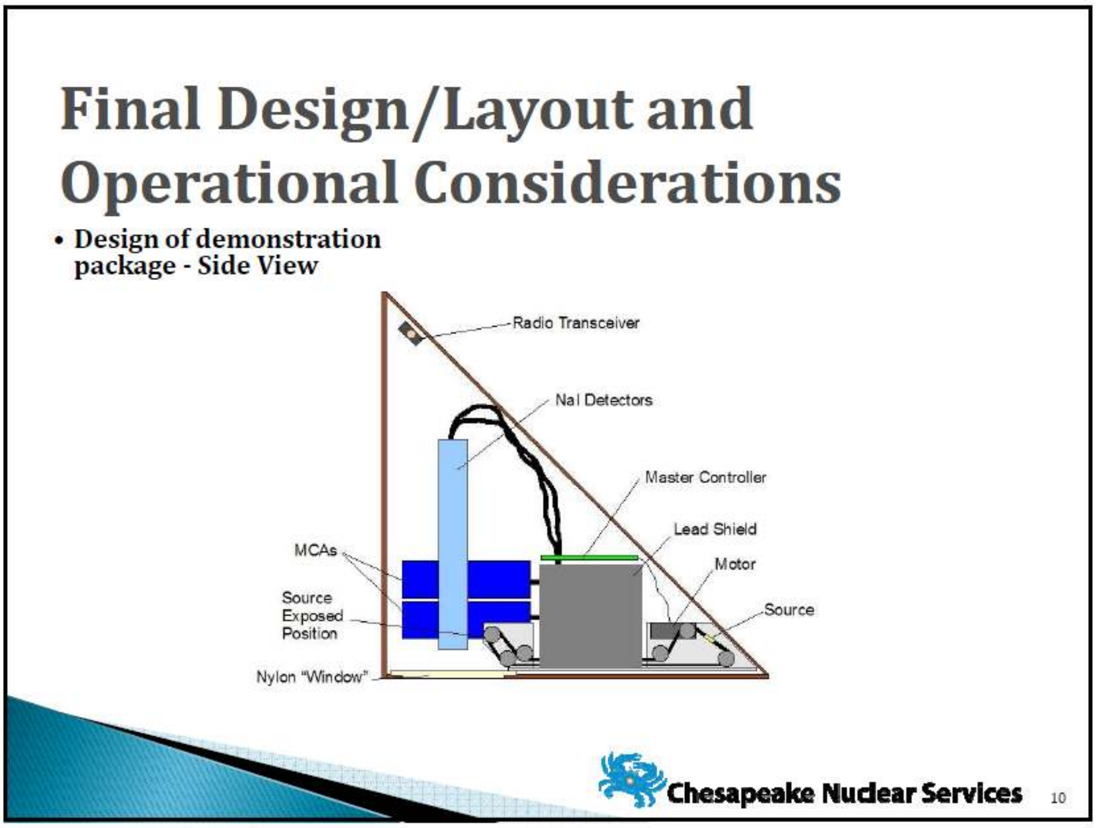
Chesapeake Nuclear Services



Final Design/Layout and Operational Considerations

- Design of demonstration package - Front View

Chesapeake Nuclear Services



Final Design/Layout and Operational Considerations

- **Design of demonstration package - Side View**

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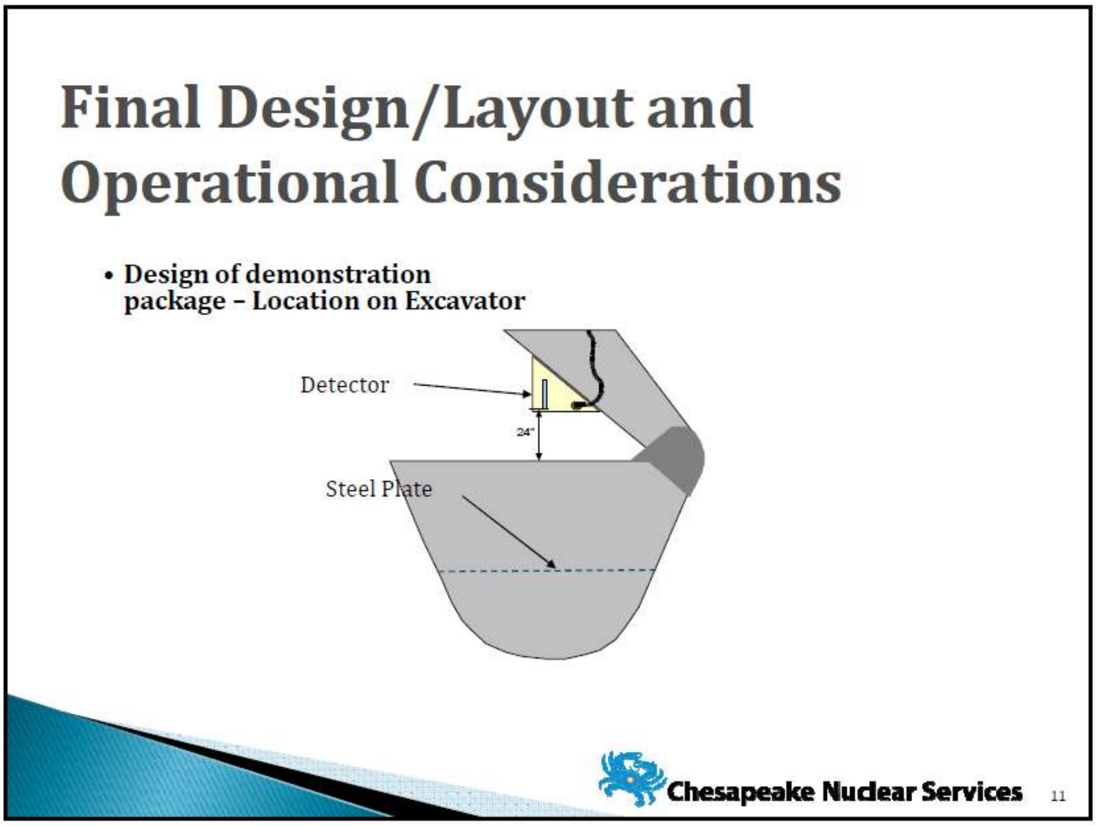

Final Design/Layout and Operational Considerations

- **Design of demonstration package – Location on Excavator**

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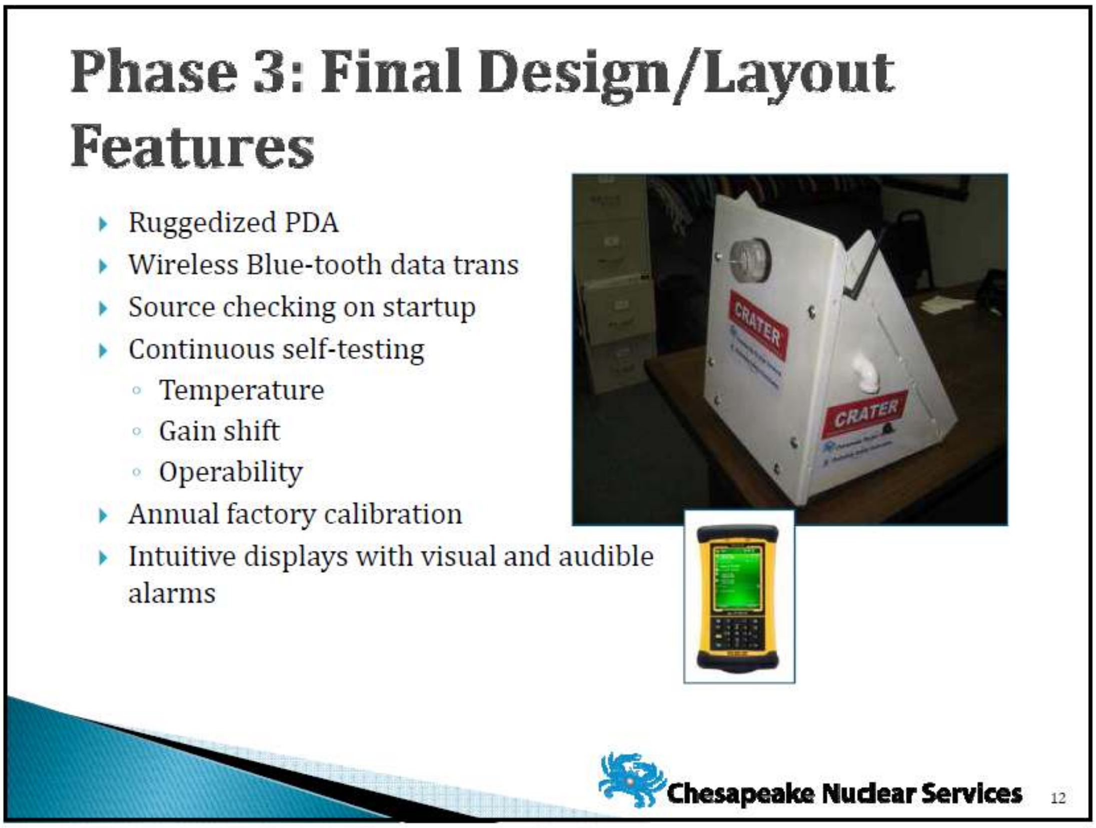
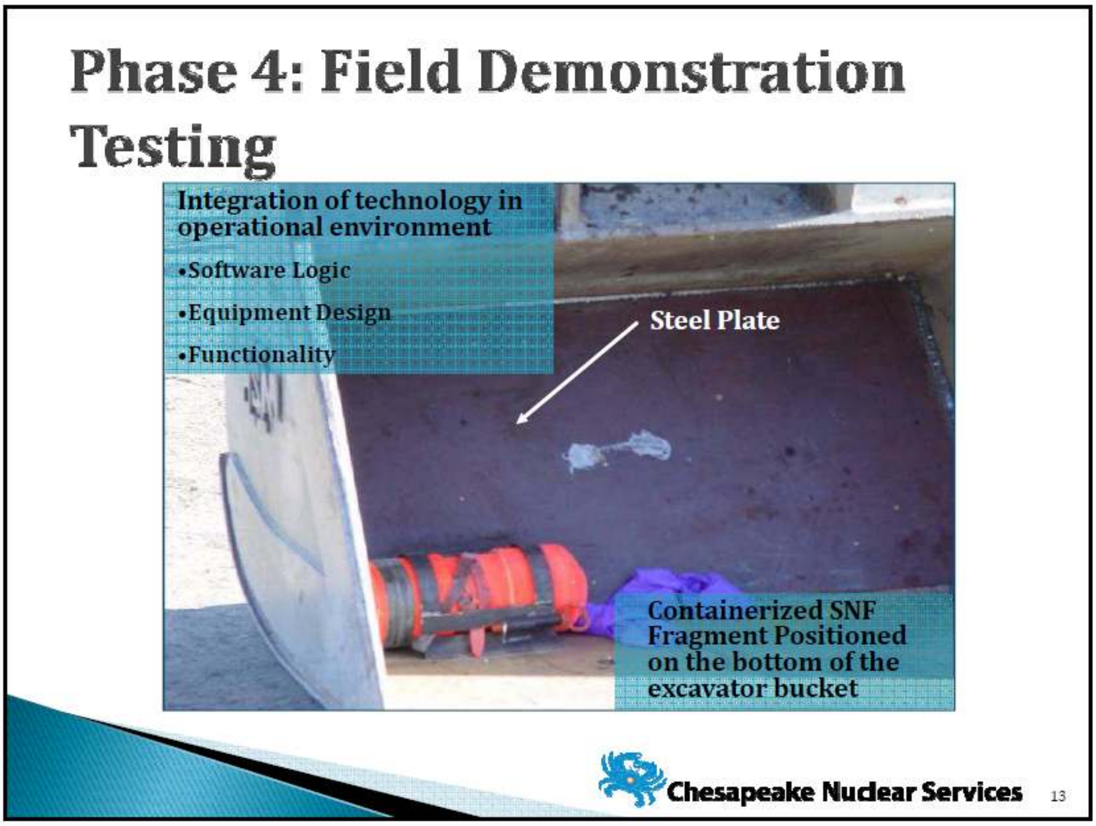


Phase 3: Final Design/Layout Features

- Ruggedized PDA
- Wireless Blue-tooth data trans
- Source checking on startup
- Continuous self-testing
  - Temperature
  - Gain shift
  - Operability
- Annual factory calibration
- Intuitive displays with visual and audible alarms



Phase 4: Field Demonstration Testing

Integration of technology in operational environment

- **Software Logic**
- **Equipment Design**
- **Functionality**

Steel Plate

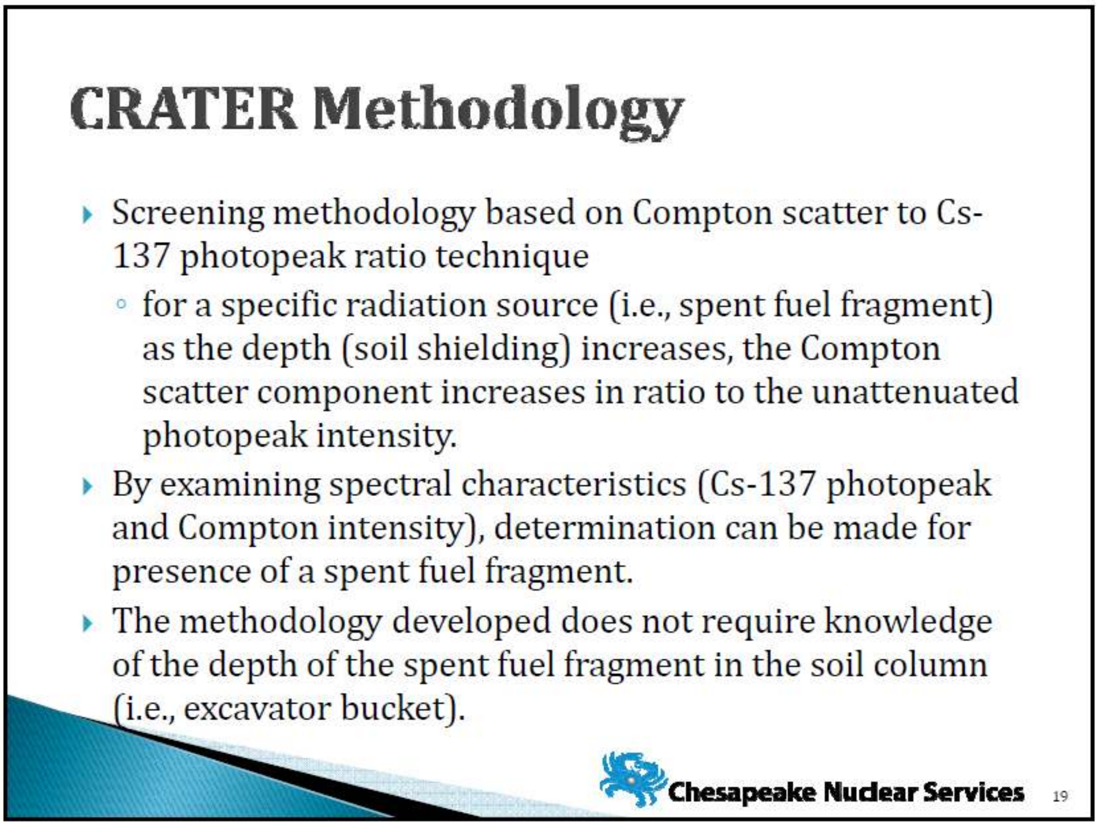
Containerized SNF Fragment Positioned on the bottom of the excavator bucket

Phase 4: Field Demonstration Testing (con't)

- Three days of testing
- Lay-Back trench soils
- Crib materials

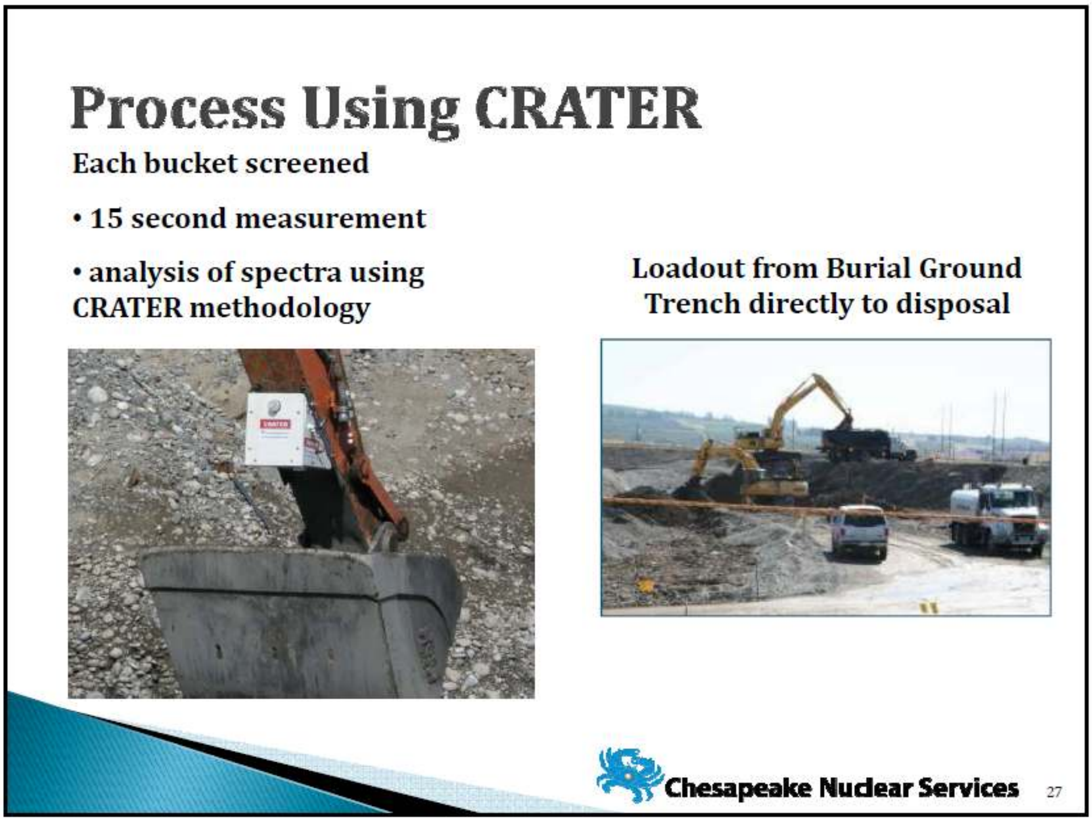
Phase 5: Improvements

- Improved Source Changer
- Redesign of interior cables
- Improved Master Control Board



CRATER Methodology

- Screening methodology based on Compton scatter to Cs-137 photopeak ratio technique
  - for a specific radiation source (i.e., spent fuel fragment) as the depth (soil shielding) increases, the Compton scatter component increases in ratio to the unattenuated photopeak intensity.
- By examining spectral characteristics (Cs-137 photopeak and Compton intensity), determination can be made for presence of a spent fuel fragment.
- The methodology developed does not require knowledge of the depth of the spent fuel fragment in the soil column (i.e., excavator bucket).

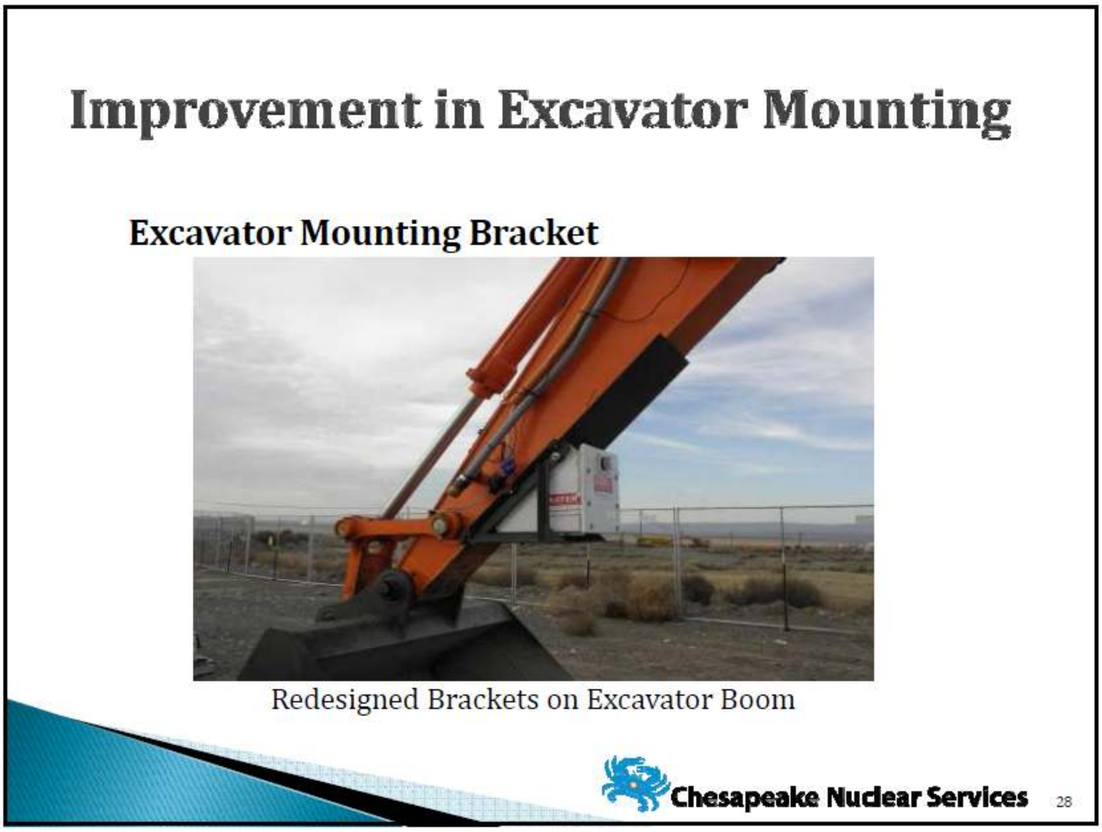


Process Using CRATER

Each bucket screened

- **15 second measurement**
- **analysis of spectra using CRATER methodology**

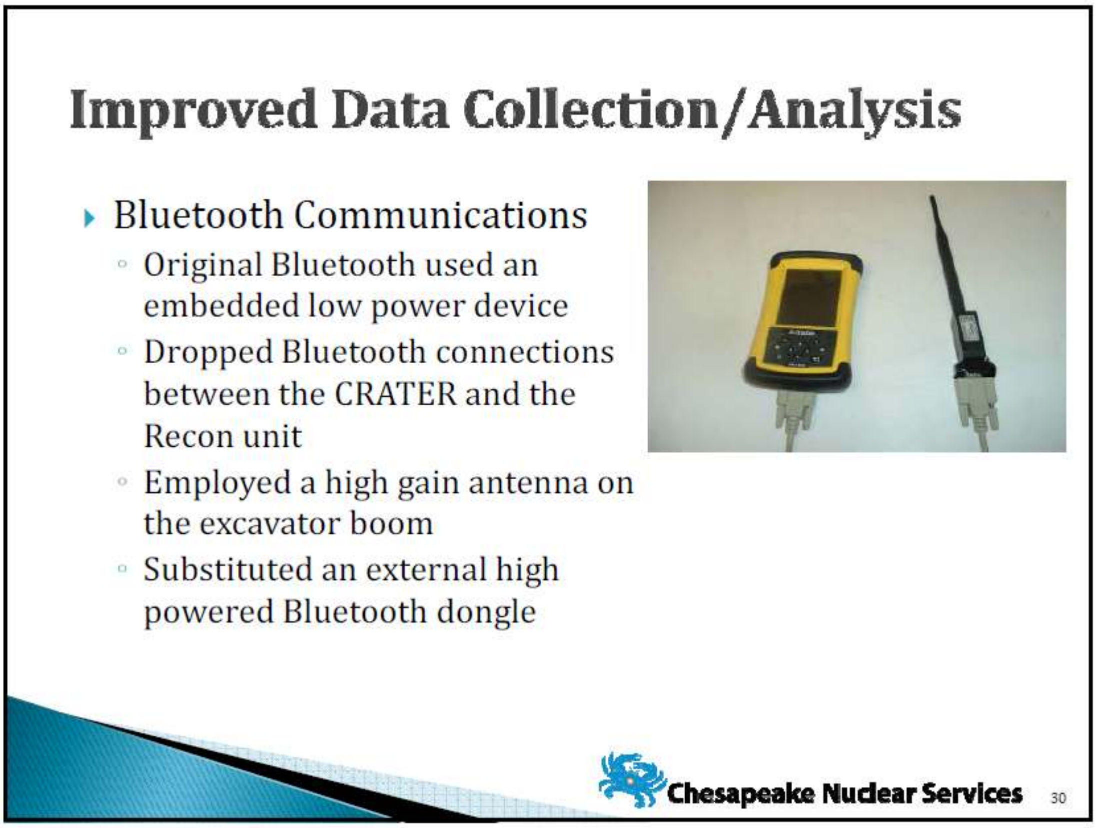
Loadout from Burial Ground Trench directly to disposal



Improvement in Excavator Mounting

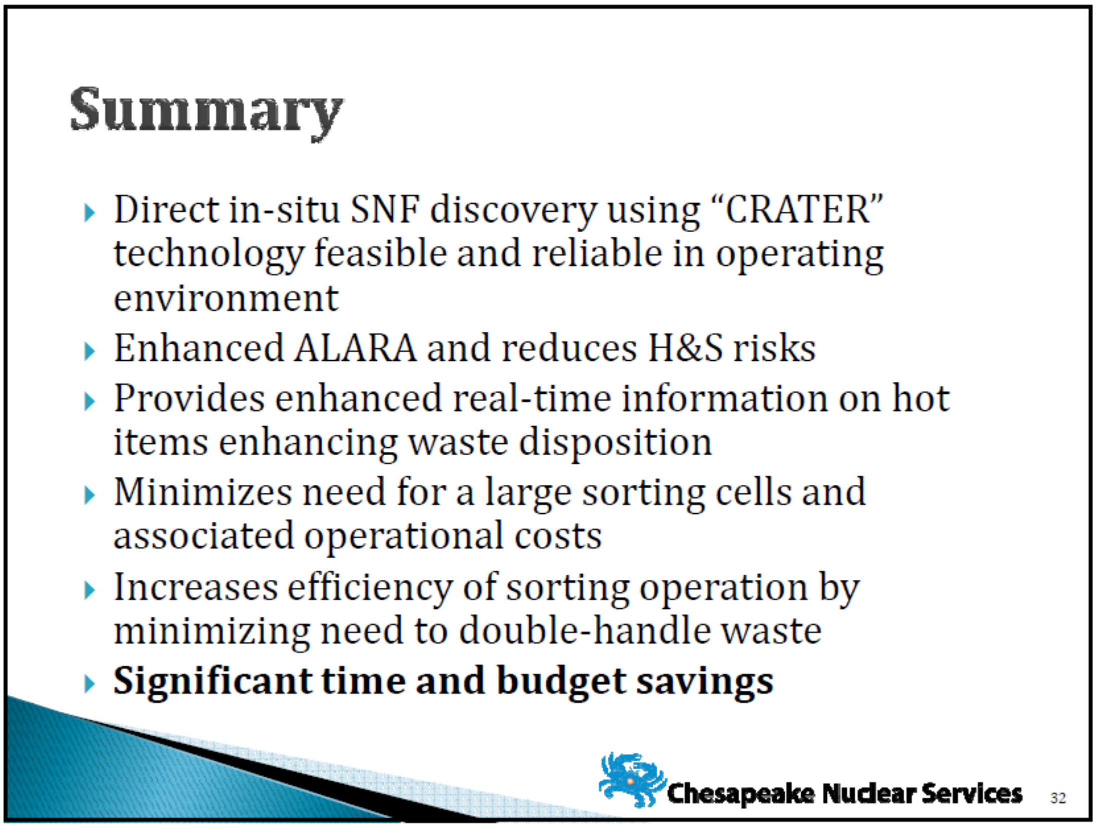
Excavator Mounting Bracket

Redesigned Brackets on Excavator Boom



Improved Data Collection/Analysis

- Bluetooth Communications
  - Original Bluetooth used an embedded low power device
  - Dropped Bluetooth connections between the CRATER and the Recon unit
  - Employed a high gain antenna on the excavator boom
  - Substituted an external high powered Bluetooth dongle



Summary

- Direct in-situ SNF discovery using “CRATER” technology feasible and reliable in operating environment
- Enhanced ALARA and reduces H&S risks
- Provides enhanced real-time information on hot items enhancing waste disposition
- Minimizes need for a large sorting cells and associated operational costs
- Increases efficiency of sorting operation by minimizing need to double-handle waste
- **Significant time and budget savings**

Chesapeake Nuclear Services

八、美國紐約洲放射性廢棄物指導文件

Radioactive Materials Guidance Document
DSHM-RAD-05-01
Cleanup Guidelines for Soils Contaminated with Radioactive Materials

I. Summary:

This Policy provides guidance to Department staff on such cleanups for soils contaminated with radioactive materials. This Policy was formally issued on September 14, 1993 as Technical and Administrative Guidance Memorandum (TAGM) Number 4003. The Policy has not been significantly amended but merely updated to reflect a new organizational structure, and reformatted in accordance with Department procedures, in order to make the policy available on the Department's web site.

II. Policy:

The total effective dose equivalent to the maximally exposed individual of the general public, from radioactive material remaining at a site after cleanup, shall be as low as reasonably achievable and less than 10 mrem above that received from background levels of radiation in any one year.

The radiation dose received from an exposure to soils contaminated by radionuclides will strongly depend on the time of exposure and pathways by which the radionuclides or their decay products can come in contact with an individual. For this reason, the estimated annual dose resulting from exposure to any residual radionuclides in the contaminated area is the basis for establishing site-specific cleanup criteria. The dose estimate is to be based on the contaminating radionuclides, but not on background concentrations of any radionuclides that may be at the site. Background radiation refers to:

(1) local area concentrations of naturally occurring radionuclides;
(2) cosmic radiation; and
(3) radionuclides of anthropogenic origin which have been regionally dispersed and are present at low concentrations (such as fallout from the testing of nuclear weapons).

III. Purpose and Background:

The purpose of this cleanup guideline is to provide:

(1) protection of public health and the environment; and
(2) consistency in implementing remedial actions at sites contaminated with radioactive materials.

IV. Responsibility:

Responsibility for the interpretation and updating of this Program Policy document resides with the Radiation Program within the Division of Solid & Hazardous Materials.

Questions regarding this policy should be directed to:

Barbara Youngberg
Radiation Section
Bureau of Hazardous Waste and Radiation Management
Division of Solid & Hazardous Materials
518-402-8579

V. Procedure:

The process of determining the appropriate cleanup requirements will generally involve measurements of radioactivity at the site, laboratory analysis of soil samples for concentrations of radioactive materials, modeling of expected doses based on the measurements and analyses performed, and evaluation of site remediation alternatives. The modeling will require determination of site characteristics critical to the migration of radionuclides, and will need to be referenced to reasonable scenarios for current and plausible future uses of the land. Consideration of the time period during which the radioactive material is expected to persist at the site will be important in the selection of scenarios for land use. The estimated dose limit of 10 mrem/year refers to land released for unrestricted use. If unrestricted use scenario calculations result in dose estimates that are greater than 10 mrem/year, it may be necessary to invoke institutional controls and/or deed restrictions so that actual doses from allowed uses are not likely to exceed 10 mrem/year.

A. Dose Analysis Methods - Analysis methods used must be acceptable to the New York State Department of Environmental Conservation (Department) Division Solid and Hazardous Materials, Radiation Program. The methods used should be appropriate to the complexity of the contaminated site and to the potential for harm. The primary criterion is that the analysis yield conservative results; i.e., the results of the analysis must predict doses no lower than are likely to actually occur. This principle should be applied to both the analysis methods and to the site-specific inputs required for any models used in the evaluation.

   All reasonable pathways of exposure shall be considered when determining the estimated dose to individuals. Approval of the procedures used in, and the interpretation of, each step of the analysis must be obtained from Department. The steps to be followed are:

   1. Perform a site assessment. This involves determining exposure levels at the site, the extent of the contamination, and concentrations of radionuclides in the contaminated areas. Care must be taken that the appropriate instrumentation is used for detecting radiation at the site (gamma, beta, alpha, or neutrons). Concentration profiles as a function of depth in the soil should be determined. Where possible, the chemical and physical forms of the radionuclides should be determined. It should be possible from this data to characterize the locations and concentrations of all radionuclides which can significantly contribute to the dose potentially received from the site. When modeling the site characteristics, and the migration of radionuclides within and

from the site, it will be necessary to show that the site parameters used will cause the dose estimates to be conservative.

During on-site investigation, Department staff and contractors must abide by all appropriate requirements and Departmental policies related to personal protection and by any applicable health and safety plans. At sites where non-radioactive contaminants are known to be present, Department Radiation Program staff should contact appropriate persons from other involved Bureaus, Divisions, or Agencies as to health and safety and coordination of activities. If non-radioactive chemical contamination (where not previously known) is suspected at a site, be it by observation and/or analysis, the appropriate Department regulatory staff should be notified;

2. Provide a review of current land use and a rationale for potential use of the site. Use this information to estimate possible occupancies for the site and review how different plausible uses of the site can contribute to exposures. Keep in mind that the maximally exposed individual of concern is a member of the general public not associated with the use of radioactive materials. This is usually a resident, but may also be a worker at a business not licensed to use radioactive materials. Radiation exposure to workers at facilities with radioactive materials is regulated by the licensing agency under the New York State Industrial Code (New York State Department of Labor) or the New York State Sanitary Code (New York State Department of Health); and
3. Analyze all reasonable pathways. Only when pathways can be shown to contribute insignificantly to the dose, can they be eliminated from further consideration. Pathways that must be considered are:
   (a) Doses from direct exposure to radiation emitted from the contaminated soil and, where applicable, from contaminated ground or surface waters; and
   (b) Doses from internal exposure - including inhalation of contaminated dust (including radon progeny if present), ingestion of contaminated soil, ingestion of food raised on

contaminated soil, and ingestion of drinking water (both aquifer and surface waters) or contaminants from irrigation water.

B. Analysis of Remediation Alternatives - Remediation techniques should be evaluated for effectiveness at meeting the 10 mrem/year dose limit, at keeping radiation doses as low as reasonably achievable, and at minimizing the creation of radioactive waste. If site remediation is needed to achieve the 10 mrem/year dose limit, it will be necessary to prepare a work plan that is acceptable to Department and other cognizant agencies (NYS Department of Labor, NYS Department of Health).

Acceptable remediation procedures might include:
1. Removal of contaminated soil for disposal at a licensed facility;
2. Isolation of contamination such as covering the contamination with clean soil. This technique may be acceptable for short-lived isotopes assuming that restrictions to land use are used until the radionuclides no longer pose a threat; and
3. Other remediation techniques, if applicable, considered and approved on a case-by-case basis.

Remediation alternatives should be evaluated for exposures which will occur to workers, Department staff, and the general public during corrective action/remedial activities. Appropriate health and safety plans should be prepared or referenced from construction and monitoring activities (see also item C.1 below).

Remedial alternatives should also be evaluated for the potential to cause significant damage to sensitive environmental or historical areas (see also item C.2. below).

Special consideration must be given to sites contaminated with non-radioactive chemicals as to remedial alternatives and disposition of the resultant hazardous or "mixed" waste.

Before a site can be released for unrestricted use, it will be necessary to confirm that the approved work plan has been completed successfully. This confirmation will include measuring exposure rates and/or measurements of residual radionuclide concentrations. The final modeling step will need to show that release of the site, with any radionuclide concentrations still remaining after remediation, will not cause the dose limit to be exceeded.

C. Alternative Procedures - There may be incidents/situations whereby:

1. The health and safety of individuals involved in a cleanup may necessitate acceptance of a dose greater than 10 mrem/year to the maximally exposed individual; or
2. The cleanup may cause irreversible destruction or loss of environmental habitat.

In such situations, remedial options will be evaluated on a case-by-case basis. Final decisions will be made by the Director, Bureau of Hazardous Waste and Radiation Management.

九、出國接待人員照片

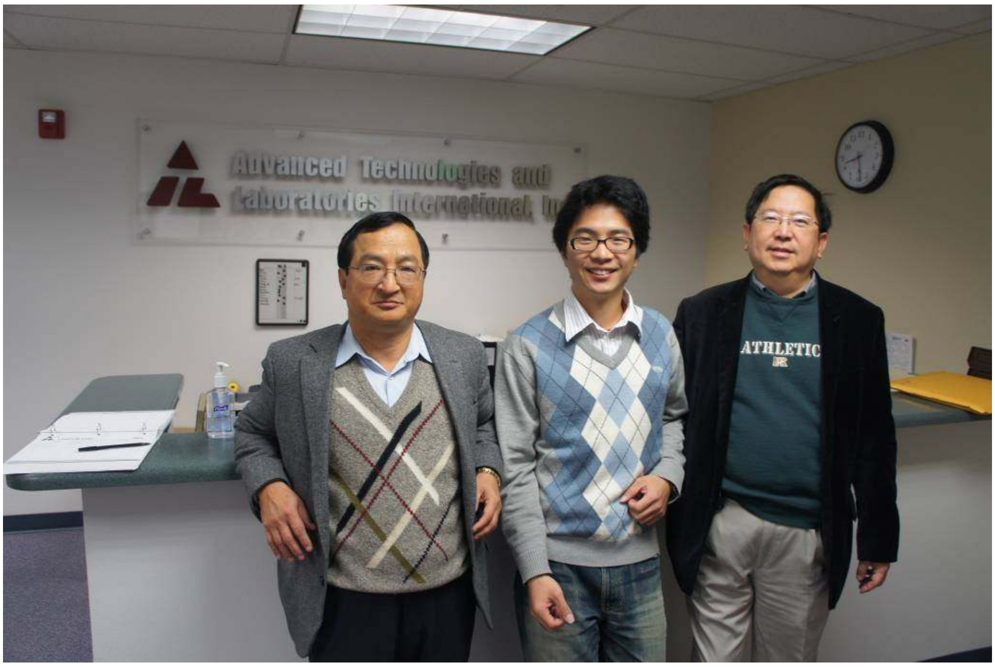


圖 A- 1　(左起)Dr. Chuanfu Wu，我及 ATL President Dr. Jou Hwang

圖 A- 2　與 Dr. Chuan-Fu Wu 合照

圖 A- 3　(左起)Mr. Tom Harper 及 Ms. Tracy Reavis

圖 A- 4 (左起)Dr. Chuan-Fu Wu 及 Dr. Caper Sun

圖 A- 5 Dr. Jou Hwang 及 Mr. Cruz R. Gonzalez