DISTINCTIVE Work Package 3: Legacy Ponds and Silos Wastes

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- Imperial College London and Birmingham University.

Sellafield Legacy Ponds and Silos: High Hazard Programmes.

Pile Fuel Storage Pond

First Generation Magnox Fuel Pond

Magnox Swarf Storage Silos

Pile Fuel Cladding Silo

HAL (Highly-Active Liquor) Workstream

Legacy Ponds & Silos

- 22% of all site programmes
- 35% of total site costs during next 4 years
- 77% of major project costs during next 4 years
- >90% of nuclear hazard potential on Sellafield site

NDA LP&S Strategy Objectives

- Acceleration of High Hazard/High Risk Reduction
- Restore and maintain the basic condition of the assets and facilities.
- Reduce or mitigate the impact of the risk of a loss of containment of Nuclear Materials.
- Prepare the facilities for retrieval operations
- Retrieve the waste (hazards)
- Immobilise the waste (hazards), e.g. research into novel thermal methods.

Pile Fuel Storage Pond

Legacy

- Constructed 1948 – 1952 to store, cool and prepare Windscale Pile fuel for reprocessing
- Waste consists of fuel, sludge and miscellaneous Intermediate and Low Level Waste

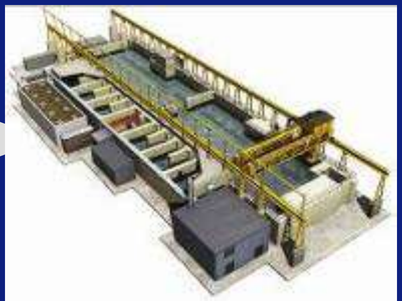
Baseline Plan

- Sludge retrievals to an in-pond corral
- Local Sludge Treatment Plant* (LSTP) for short term storage of sludge
- Local Sludge Treatment Plant Process & Export* (LSTP P&E) to package sludge into $3m^3$ boxes and export for long term interim storage
- Oxide fuel to Oxide Fuels Storage Ponds for reprocessing
- Metal fuel to Fuel Handling Plant (FHP) for interim storage
- Remaining solid ILW inventory to pond solids conditioning facility, and packaged into $3m^3$ boxes for long term interim storage

Pile Fuel Storage Pond

- Operating Plan targets 2011/12:
  - Pile Fuel Storage Pond Hazard Reduction
  - Retrieval and Export of 20te Contaminated Items
  - LSTP Storage, Commissioning Tests
  - Initiate Project Delivery Gate for sludge process and export project
  - Wash 80 skips to support retrieval of pond solids and fuel
  - Commit Sludge to LSTP Storage Tanks
  - Start canned fuel export
- Operating Plan targets 2012/13:
  - Retrieve and Export x tonnes of contaminated item
  - Rate of Export of canned fuel
  - Milestone 1 - Sludge - produce recommendation for disposal of Pond Sludge
  - Milestone 2 - Sludge - Actively demonstrate the route
- Operating Plan targets 2013/14+:
  - Last canned fuel exported

Clearing Sludge from Pond sections. Completing storage facility construction. Removing redundant skips.



WP3: Aim and Objectives

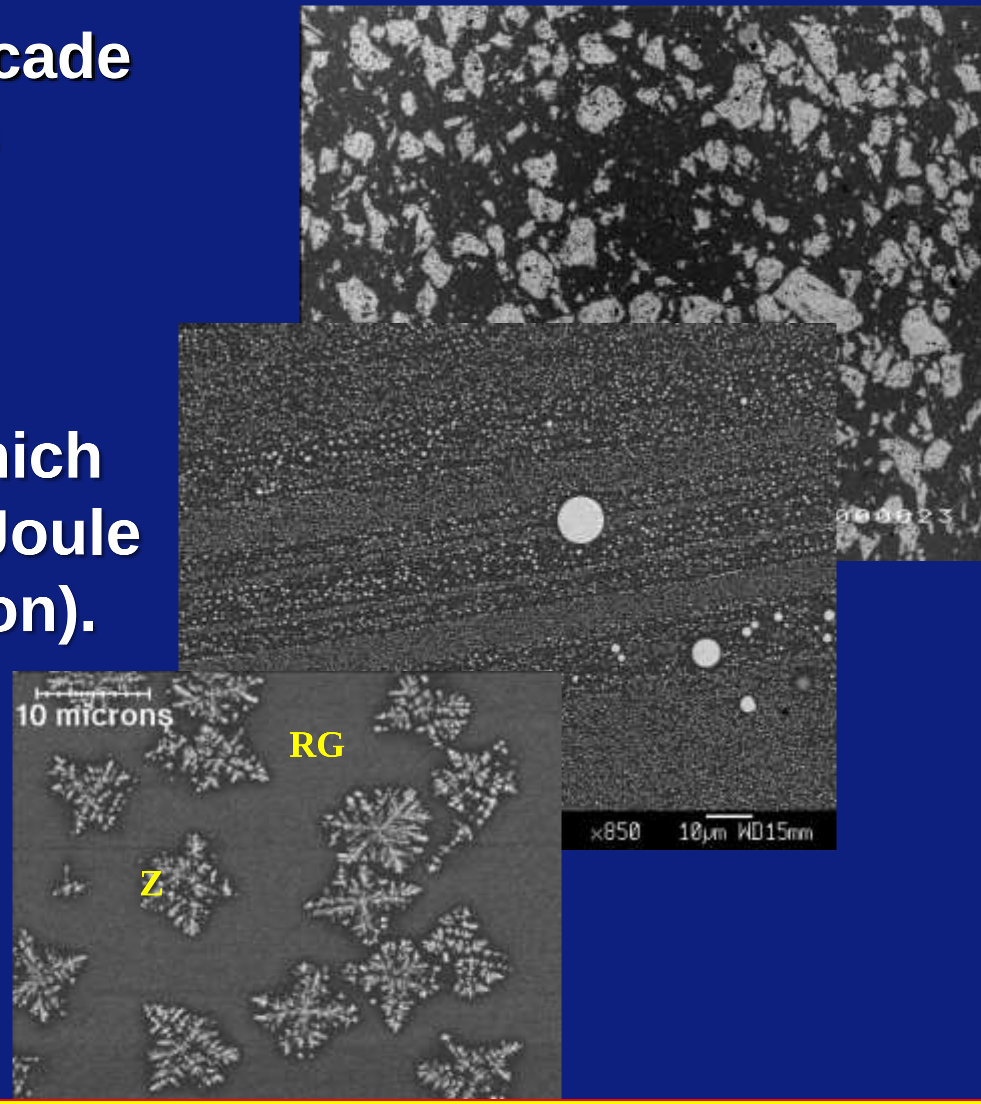
- **Aim. To develop innovative technical approaches to clean up UK legacy wastes.**
- **Objectives.**
  - To understand durability of heterogeneous ILW glass/ceramic wasteforms from LP&S wastestreams.
  - To develop improved ways to remove radionuclides (RNs) from solution, both novel inorganic ion exchange solids and tailored binding superparamagnetic nanoparticles, to treat complex and variable effluents.
  - To develop new micro- and ultra-filtration methods for use with sludges.
  - To provide three-dimensional modelling and simulation for sludge disturbance, mobilisation and transport, with supportive experimental studies, and manipulation planning for removing corroding nuclear materials.
  - To develop a better understanding of gas hold-up in sludges.
  - To develop improved techniques for remote monitoring of sludges and heterogeneous wastes.

WP 3.3.1 Wasteform Durability
Lee & Grimes (Imperial), Hyatt (Sheffield)

- PDRA and 1 PhD.
- Durability of Heterogeneous ILW Glass/Ceramic Wasteforms from Complex Wastestreams.(PDRA Lee/Grimes).
- Thermal Treatment Processes (PhD Hyatt, Sheffield)
- Charlie Hutchison and Dimitri Pletser (PhDs Imperial, not DISTINCTIVE)

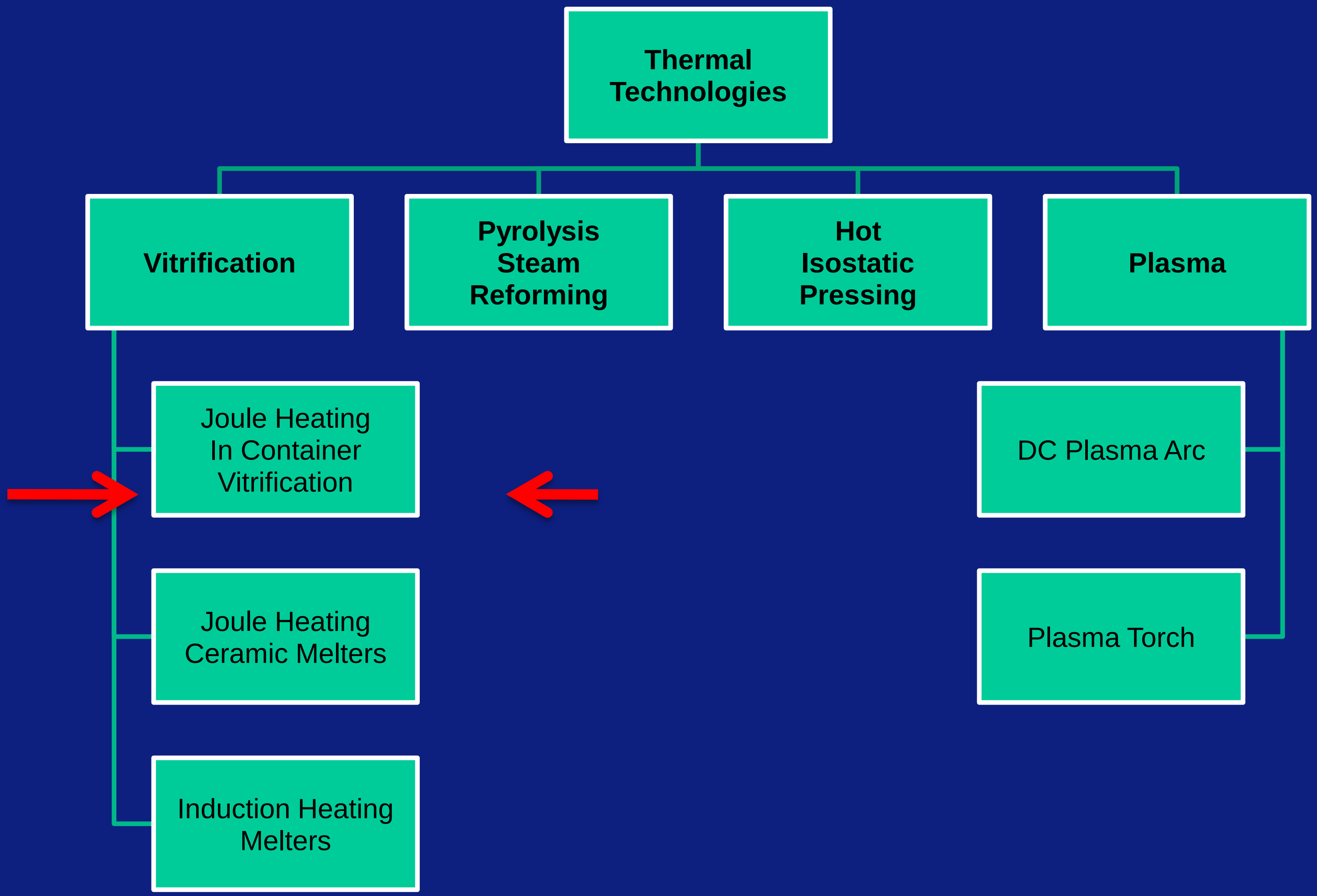
Novel Wasteforms: Glass Composite Materials (GCMs) from Thermal Technologies

- Realisation over last decade that mixed crystal-glass wasteforms can be as durable as pure glass.
- E.g. crystalline waste encapsulated in melt which solidifies to glass (e.g. Joule Heater In-Can Vitrification).
- Applicable for some LP&S wastes.



WE Lee, MI Ojovan, MC Stennett and NC Hyatt, “Immobilisation of Radioactive Wastes in Glasses, Glass Composite Materials and Ceramics,” Adv. Applied Ceramics 105 [1] 3-12 (2006).

Wasteforms from Novel Thermal Processes



Range of available technologies with differing Technology Readiness Levels.

Proof of Concept Trials using Surrogates

- Demonstrated potential of thermal treatment options to treat several LP&S wastes and they
  - can handle Sellafield LP&S wastes
  - are deployable at Sellafield
  - produce a durable product
  - offer cost benefits

- E.g. Joule Heater In-Can Vitrification – Mixed solids & sludge waste

Before

During

After

Key Issues of Thermal Processes.

- Convert reactive material (e.g. metals, sludges & organics) to more stable forms. But the following need addressing:
  - Variable nature of wastes make control of process and product difficult.
  - Difficult to characterise heterogeneous waste and product.
  - Durability testing of product.

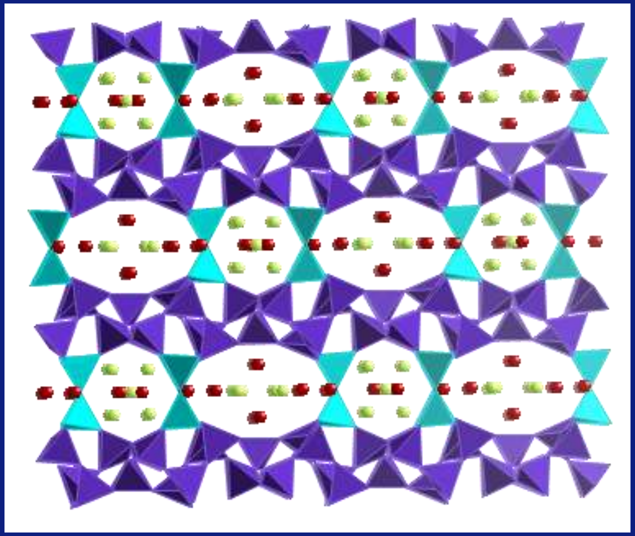
- PDRA will model aqueous corrosion of heterogeneous wasteforms from novel thermal processes and link with experimental programmes on durability at Sheffield and Imperial.

WP 3.3.2 Effluent Treatment and Analysis *Hriljac & Read (Birmingham), Evans, Platt & Holdich (Loughborough) Ryan & Vandeperre (Imperial)*

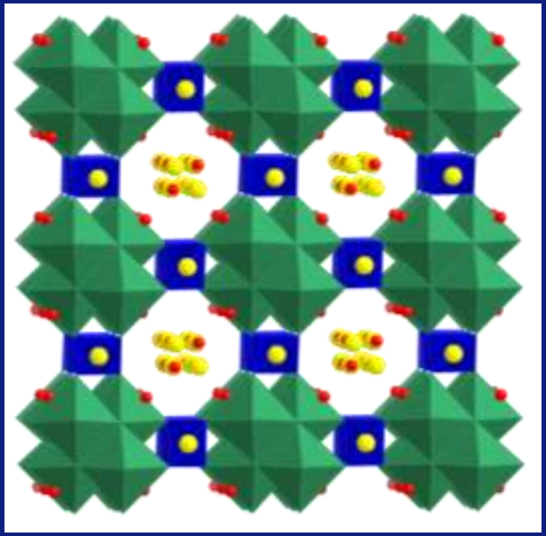
- **PDRA and 3 PhDs.**
- **Novel Ion Exchange Materials (PDRA Birmingham, Hriljac/Read,).**
- **Magnetic Nanoparticles for Waste Separation or Sequestration (PhD Imperial, Ryan/Vandeperre, O’Brien NNL; PhD Loughborough, Evans/Platt,)**
- **Enhanced Shear Micro- and Ultra-filtration Without Recycle Pumping (PhD Loughborough, Holdich,)**

Ion Exchange Materials

- **Effluent clean-up for removal of soluble radionuclides such as Cs-137 and Sr-90 traditionally rely on an ion exchange process with a porous inorganic solid**



zeolite clinoptilolite
$(Na,K,Ca)_3Al_3Si_{15}O_{36}$~$10H_2O$



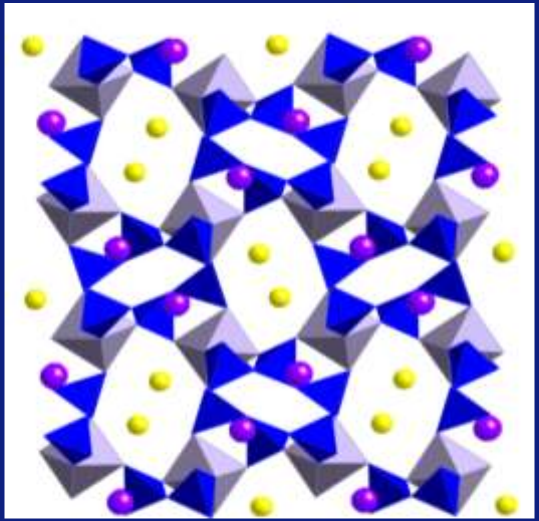
Acid form of CST in IONSIV
$Na_{0.4}(H_3O)(Ti_{1.4}Nb_{0.6})O_3SiO_4$~$2H_2O$

Ion Exchange Materials

- Limitations of current systems include
  - Variability of source for natural materials such as clino
  - Cost, e.g. IONSIV contains substantial amounts of Nb (in a 1995 Hanford clean-up of 187,000 m^3 of liquid HLW ca. $163M was allocated to purchase the IONSIV)
  - Efficacy under acidic conditions
  - Unknown efficacy in the presence of complexants and/or decontamination agents
  - Potential for back exchange under storage conditions
  - Conversion routes to good wasteforms for long term storage

Novel Ion Exchange Materials

- **Use atomistic modelling to pre-screen mineral phases to predict best candidates for ion exchange**
- **Make phases via hydrothermal and/or microwave routes**
- **Characterise and test for ion exchange properties**
- **Investigate thermal processing routes including HIPing to make dense wasteforms**



- **$(Na,K)_2SnSi_3O_9 \cdot H_2O$**
- **K_d for Sr nearly as good as IONSIV and SIXEP clino**
- **Thermally converts to a dense phase**
- **Work of current PhD student Sav Savva (NDA bursary)**

WP 3.3.3 Pond and Silo Sludges

Day & Scott (Bristol), Fairweather & Peakall (Leeds), Kerridge (UCL).

- **PDRA and 3 PhDs.**
- **Measurement and Modelling of Sludge Mobilisation and Transport (PDRA Leeds, Fairweather/Biggs).**
- **Gas Hold-up in Sludges (PhD Leeds, Peakall/Biggs)**
- **Computational Simulations of Storage Pond Sludge Disturbance (PhD UCL, Kerridge)**
- **Development of Raman Spectroscopy Techniques for the Remote Analysis of Nuclear Wastes in Storage (PhD Bristol, Day/Scott,)**

Measurement and Modelling of Sludge Mobilisation and Transport

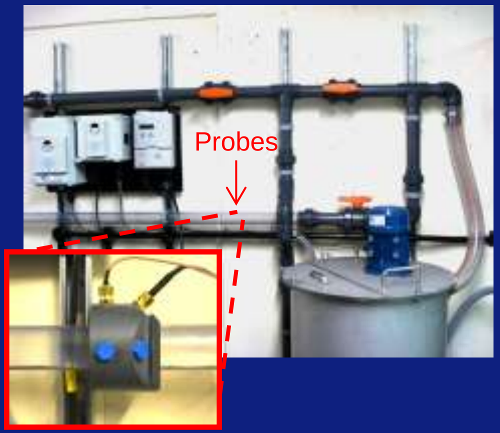
- Current understanding of behaviour of nuclear waste sludge during mobilisation and transport poor due to:
  - Complex nature of particle phase (size distribution, shape, density, etc.)
  - Limited availability of useful data for these materials

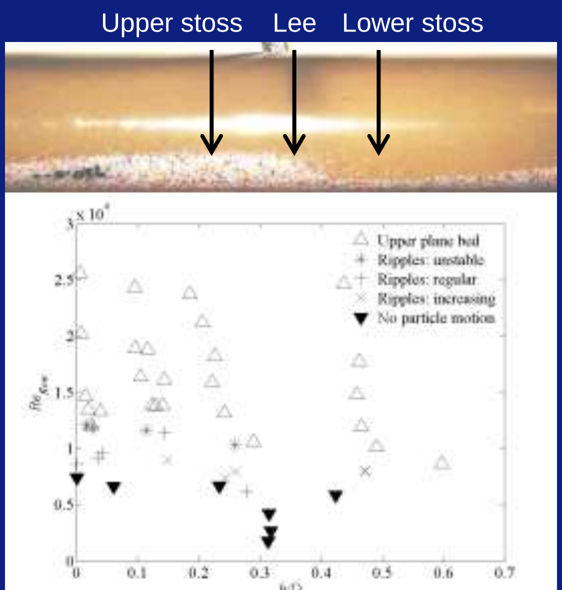
- Further understanding of sludge materials, and development of quantitative predictive procedures, necessary for:
  - Design of more efficient and safer treatment processes

  - Reductions in cost and operational timelines
  - Improved understanding of operational problems

Measurement and Modelling of Sludge Mobilisation and Transport

- Linked work to be undertaken by PDRA(s) on two projects
- First project will use realistic sludge simulants (recipes from NNL/Sellafield):
  - With range of particle shapes, sizes and densities
  - Examine behaviour of particle-laden flows, at various solids concentrations, in horizontal and vertical pipes
  - Characterise segregation behaviour of particle materials using novel ultrasonic approaches





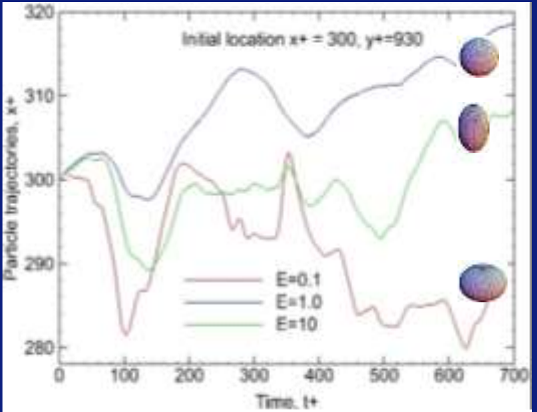
Bedforms in turbulent pipe flow

Measurement and Modelling of Sludge Mobilisation and Transport

- Second project will use coupled large eddy simulation/Lagrangian particle tracking to simulate pipe flows and:
  - Influence turbulence and direction gravity on particle agglomeration, settling, and shear break-up
  - Range of particle shapes, sizes and densities
- Overall aim to provide validated method for complex flows in geometries relevant to waste processing operations
- Results of benefit as touchstone for pragmatic models used by industry

Spheres only	Rods only	Rods and spheres

Settling behaviour of different shaped particles



Trajectories of different shaped particles in flow

Making History – First UAV deployment at Sellafield with successful radiation mapping

Apologies from Dr Tom Scott for his absence today. He only just finished this and is on his way back down as I speak!

- 15 successful UAV flights
- Mapping radiation at 3 different locations including contaminated land, an R3 storage compound and building.
- No crashes!

Future ambitions to overfly the ponds to provide dose readings.

Going out to Fukushima on the 14th May to map there.

WP 3.3.3 Pond and Silo Sludges
Day & Scott (Bristol)

– **To develop improved techniques for remote monitoring of sludges and heterogeneous wastes.**

- Development of laser and fluorescence imaging techniques for remote identification of key waste products in wet places.
- Miniaturisation and integration of prototype sensors with existing mobile platforms (ROVs, snakes).

Underwater trials in Bristol and then hopefully ponds

- Based on UoB excellence in sensor integration with mobile platforms, miniaturised Raman probes and fluorescence imaging units.