Providing an Integrated Offer for Today’s Waste Management Challenges
Veolia Nuclear Services
Emerging Leader for Global Nuclear Market

- Veolia Nuclear Services the Global Nuclear Market
- Draws on the expertise across the entire VEOLIA Group
- One entity dedicated to nuclear activities
- KURION-VEOLIA
  - Access/Robotics
  - Separation
  - Stabilization
  - Technical Services
- ALARON
  - Asset recovery and decontamination
- ASTERALIS
  - Investigation and Characterization
  - Operation and Services

*Spanning the complete value chain in the clean-up and treatment of nuclear equipment and waste*
Kurion-Veolia Global Footprint

- **$170 Million revenue**
- **300 Employees**

**Kurion**
- Wampum (USA/PE) • Asset recovery and Decontamination Plant
- Ellesmere Port (UK) • LL&MLW Incineration Plant
- Sellafield (UK) • Geomelt Processing Facility
- Tokio (Japan) • Regional office
- Lyon (France) • Radiological analysis laboratory
- Richland (USA/WA) • Engineering
- Loveland (USA/CO) • Remote systems engineering and design office
- Houston (USA/TX) • Detritiation Test Facility (bench scale)
- Tokyo (Japan) • Iga City (Japan) • Geomelt Processing Facility
- Manchester (UK) • Regional office
- Abingdon (UK) • Oxford Technologies, Ltd.

**Veolia**
- Asteralis & Alaron
D and D Waste Management Challenges
Different Issues Through the Project Phases

- **Removal of Spent Fuel**
  - Removal and packaging techniques and technologies are mature
  - Disposal is technically achievable, but in political realm

- **Highest Risks to Workers and Costs**
  - Dismantlement and segmentation of reactor and its internal
  - Liquid waste streams found in systems and tanks

- **Uncertainty Comes from Demolition of Building, Equipment and Other Parts**

- **Political Need for a Proof of Completion**
  - Identification of disposal routes
  - Compliance with final radioactivity levels

Source: www.nrc.gov

Source: Ignalina NPP
Veolia’s Response
Safer, Faster and Reduced Lifecycle Costs

SAFER
- Minimization of workers’ exposure to radiation (ALARA principle)
- Better and more accurate knowledge of initial data
- Use of remote access systems

FASTER
- Use of proven technologies
- Sustained through additional R&D and innovation
- To implement new approaches and technologies

REDUCED LIFECYCLE COSTS
- On-site handling and volume reduction
- Minimization of sorting, packaging dose-to-workers and transport to final disposal
- Recycling of materials

Optimization to save time and money and minimize the risks
Kurion-Veolia has the know-how and technologies that work together to allow a smarter dismantling.
Investigation and Characterization

- Dedicated Resources for D&D
- Mobile Capabilities for On-site Operations
- Surface and Contamination Mapping
Radiological Characterization and Analysis
Dedicated Resources for D&D Operations

On-site measurements
- Radiation protection measures ($H^{*}(10)$, $H'(0.07)$, …)
- Surface contamination
- Atmospheric contamination
- On-site $\gamma$ spectrometry
- Sampling operation and sample management

Laboratory
- More complex analysis
- Low detection limits
- $\alpha$-$\gamma$ Spectrometry, Liquid scintillation, ICP/MS, Proportional counting,…
- Analysis under COFRAC accreditation

Key Role at Every Step of D&D Operations
- Characterization of initial state
  - Mapping of installations
  - Sampling program
  - D&D scenarios
- Operators radiation protection
- Waste analysis and control
  - Identification, sorting and D&D waste management
  - Waste optimization
- Control of final state
  - Proof of decontamination achievement

Operational Synergies Between On-site Measurements and Laboratory
- Common teams
  - Reactivity
  - Information and data management
  - Adequacy between sampling operations and analytical needs
Radiological Characterization and Analysis
On-Site Capabilities and Benefits

- **Mobile Gamma Spectrometry**
  - High qualified personnel
  - Mobile system - easy for air transport, train...
  - Wide energy range covering all field situations
  - Ready to use in about two hours, anytime, anywhere
  - Wireless with tablet PC operating full Genie 2000
  - Electrical cooling - Internal hot swappable batteries for minimum 6–8 hours of continuous operation

- **Unit Efficiency Calibration**
  - Use of ISOCS (In Situ Object Counting System) Calibration Software to eliminate the need for traditional calibration sources
  - Accurate qualitative and quantitative gamma assays of most any sample type and size

Ensure realistic on-site measurement by representative sampling & measurements of beta/gamma emitters

Ensure perfect correlations between laboratory analysis and on-site measurements

Ensure accurate qualitative and quantitative gamma assays of various sample types and sizes

Comply with local safety, radiation protection and environmental regulations and monitor activities

Realize complete mapping of areas, waste & equipment before and after cleaning operations

Ensure perfect correlations between laboratory analysis and on-site measurements
Radiological Characterization and Analysis
Surface and Contamination Mapping

- **Surface Characterization**
  - NaI / or gamma probe + radiometer
  - Irradiation measurement
  - Gamma spectrometer measurement
  - Radar operations

- **Intrusive Characterization**
  - Sonic drilling (soils- 15 m)- dry method
  - Horizontal, vertical and slope position
  - Drilling of installations perimeters (drilling a distance or on site)
  - Sampling at small deep (3-5 cm)
  - Sampling on waste
Radiological Characterization and Analysis
Examples of Contamination Mapping

2D mapping

3D mapping
Remote Access

- Systems and Services
- Tanks
- Reactor/Nuclear Facility D&D
Remote Access Systems and Services

- One of the most experienced teams in advanced engineering, robotic technologies and special tooling
  - >200 robotic systems delivered
  - >2000 remote tools on tank and reactor projects

- Technology Maturity
  - Hundreds of diverse projects in hazardous environment
  - Success at the most demanding sites
  - Working on D&D of the Fukushima reactors since 2014

- Project Examples
  - Fukushima : Remote inspection manipulator, Remote repair manipulator, Fuel removal concept
  - Hanford : 324 Building excavation
  - Dounreay : Shaft and Silo
  - ITER : operation and maintenance manipulators

### Project Calendar

<table>
<thead>
<tr>
<th>Date</th>
<th>Project</th>
<th>Client</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 - Current</td>
<td>Fukushima Fuel Debris Removal</td>
<td>IHI</td>
<td>Present Day</td>
</tr>
<tr>
<td>2014 - Current</td>
<td>Fukushima Torus Repair Manipulator</td>
<td>IHI</td>
<td>Present Day</td>
</tr>
<tr>
<td>2012 - 2014</td>
<td>Fukushima Torus Inspection Manipulator</td>
<td>IHI</td>
<td>Present Day</td>
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<tr>
<td>2009 - 2012</td>
<td>Transpyndor Rotary Deployment Arm</td>
<td>Magnox</td>
<td>Present Day</td>
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<td>2007 - 2008</td>
<td>Hanford Tank Arm Demo</td>
<td>CH2M Hill</td>
<td>Present Day</td>
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<tr>
<td>2006</td>
<td>SRS Skid &amp; Arm</td>
<td>WSRC</td>
<td>Present Day</td>
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<tr>
<td>2005</td>
<td>S3D3P Arm</td>
<td>INS Innovation</td>
<td>Present Day</td>
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<tr>
<td>2003</td>
<td>Rancho Seco Acoustic Vessel Segmentation Arm</td>
<td>SMUD</td>
<td>Present Day</td>
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<tr>
<td></td>
<td>West Valley Long Reach Manipulator</td>
<td>WVNS</td>
<td>Present Day</td>
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</tbody>
</table>

Left to Right: Medium Tools (Type 1,2,3), Inflatable Bag Tool, Guard Tool
Remote Access
Tanks – Waste Gathering, Inspection and Repair

Long Reach, High Payload Manipulator Systems

- Able to Deploy a Variety of Tools for Various Remote Operations
- Able to Fit Through Existing Tank Penetrations
- Sludge / Liquid Removal
- Sludge / Liquid Recovery and Processing
- Quick Change-out End Effecters and Tooling
- Remote Control via Touchscreen and Joystick Input
- Camera Viewing via Integrated In-Tank Viewing System
Remote Access
Reactor/Nuclear Facility D&D

- Practical, Proven Solutions to Complex Problems
- Design, Build, Test and Deployment of Decommissioning Services and Equipment
- Customized Off-the-Shelf Construction Equipment (i.e. Excavation Equipment)
- Integrated Systems to Perform Numerous Remote Operations
- Turn-Key Approach and Engineering Approach to Complex D&D Projects
  - Approach to 324 Hot cell Remediation Approach at Hanford Being Finalized
- Applicable to NPP Decommissioning.
  - Specifically Reactor and Internal Segmentation
References: Remote Access Systems & Services

Windscale Piles Reactor D&D
- Sellafield UK
- 2004-2012
- Client: UKAEA
- Design of decommissioning Approach including extensive Prototype testing of custom fuel removal, processing and packaging equipment

324 Hotcell Remediation
- Hanford, WA
- 2014 - Present
- Washington closure Hanford and CH2M Plateau Remediation Company
- Responsible of 100% of the engineering design, including facility stabilization, building modification and robotic systems for floor and soil removal.

Brookhaven Graphite Reactor D&D
- Upton, NY
- 2008-2010
- Brookhaven Science Association
- Prime contractor responsible for the design, fabrication of a complete Turnkey Dismantlement system using modified commercial equipment

UK
- Sellafield
- B30 Powered Manipulator
- B38 Silo
- B41 D&D concept
- Dounreay
- Shaft and silo cleanout
- D1251 Pie Cave PRM
- Trawsfynydd
- Studvistik Generator D&D
Separation

- Soluble Radionuclides
- Suspended Particles
- Advanced Separation Technics
- Solid Waste Separation
Soluble Radionuclides
Ion Specific Media (ISM)

- **ISM**
  - Series of proprietary and patent-pending inorganic media
  - Selectively removal of specific ions from aqueous waste streams

- **Technology Maturity**
  - First-of-a-kind external reactor system since 2011 (>300,000m³ processed)
  - First-of-a-kind at-tank isotope removal system since 2014

- **Project Examples**
  - Fukushima : Cs + Sr Removal in reactor recycle loop
  - Fukushima : KMPS for Sr removal from tank water
  - Magnox : Pond water purification
  - Cimarron Fuel Processing Plant : U removal from groundwater

- **Kurion Mobile Processing System (KMPS)**
  - Skid-mounted assemblies used for at-tank mobile isotope removal to treat radioactive water stored in hundreds of water storage tanks on-site at Fukushima. The system in this case is primarily used to remove strontium from the water with a process rating of 300m³/day – since Oct 2014

90% - Cesium reduction level
Soluble Radionuclides
METCLEAN™

- Selective Co-precipitation using Fe or Mn-based chemistry
- Clean Water to Very High Quality Produced
- ‘Granulate’ Stream can be Concentrated via Ultra-Filtration (UF)
- Concentrate for Disposal Route or…
- Evapo-Condensation for Further Volume Reduction
- Final Solid to Incineration
Suspended Radionuclides Particles
Filtration Technics

• Basic Filtration (1 to 50µm) on granular material or sieve (pocket or cartridges)

• Continuous Filtration
  MF – Microfiltration (< 1 µm)
  UF – Ultrafiltration (< 0.05 µm)

• Ceramic Membranes CERAMEM®
Suspended Radionuclides Particles
ACTIFLO® Froth Flotation

- **ACTIFLO®**
  - Compact solution for liquid/solid separation
  - Operates with microsand as a seed for floc formation
  - Designed for very high flow rates and short retention times

- **ACTIFLO® Allows Removal of Soluble Radionuclides With:**
  - Fe or Al salts coprecipitation
  - CaCO3 coprecipitation
  - Adsorption on adsorbent powder (GAP, zeolite....) or preformed precipitates

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**PRINCIPLE OF ACTIFLO™-RAD TECHNICAL PROCESS**

- **CONTAMINATED WATER**
  - Flotation Unit
  - 1st Pre-Contact Tank
  - Multi-Flo™
  - 2nd Pre-Contact Tank
  - Hydrocyclone
  - Actiflo™
  - Interim Storage in Silo
  - Final Conditioning
  - Decontaminated Water

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Advanced Separation Technics
Modular Detritiation System (MDS®)

Facility Exterior

Full Scale Prototype MDS® Constructed and in Hot Ops
First proven cost-effective Light Water Detritiation System

- Processes low to high concentration tritiated water
- Discharges clean release $H_2$ and $O_2$
- Improved combined electrolysis and catalytic exchange (CECE) system
- Prototype system reduces water volume by 40x
- Kurion has adopted the TRL process to ensure technology maturation (at least TRL 6) to support low risk deployment and operation
- Kurion continues to optimize the technology through experiments and modeling. Key performance metrics have increased up to 100x since March 2016
Solid Waste Segregation
Continuous Soil Sorting Unit

- Co-development With Areva
  - International Patent
- Initially Designed for Sorting of Cs Contaminated Soil in Fukushima
  - 500 km² contaminated soil around Fukushima
  - Design, Build and Operation of a mobile unit
  - Proven sorting efficiency
  - High sorting rates (100 t/hr) on Cs
  - Detection limit for Cs at 200 Bq/kg
- Radwaste Capabilities
  - Modular measuring device, adapted to specific radioactive spectrum
  - Modular flowrate, allowing accurate segregation
Solid Waste Decontamination

- US Based Facility, Worldwide Expertise
- Highly-experienced Technicians Adept at Processing Radioactive Equipment and Materials for Disposal or Recovery

Related Services
- Asset Recovery & Decontamination
- Coatings & Painting
- Dry Active Waste
- Licensed Facility Access
- Machine Shop
- Metals & Large Components
- Motor & Pump Refurbishment
- Source Recovery
- Contaminated Asset Storage
- Nuclear Transportation
- Lead Blankets
References: Separation

ISM: External Reactor Water Cooling system
- Fukushima
- 2011
- Design iteration and fabrication 24/7 for 5 weeks
- System removed 70% of the initial inventory of 14 millions of Cesium activity

ISM Kurion Modular Process System
- Fukushima
- 2014 - 2015
- Strontium removal from aqueous solution
- Skid mounted in ISO container
- Reduce contamination by up 1000x
- ISM vitrifiable for long term disposal

Contaminated Sorting Soil Unit (CSSU)
- Developed for Fukushima
- 2011
- Fully automated, based on a binary method for continuous sorting of solid materials contaminated with radionuclides on the basis of a quantitative measurement of radioactivity
- Nominal rate of 100 t/h to a sorting resolution of the order of 50 kg. The detection limit of 0.1 Bq/g. All types of materials can be sorted, (mineral, vegetable, metal, ...).
Radioactive Waste Treatment

- Evaporation
- Incineration
- Cementation
- Geomelt®
- Modular Vitrification System (MVS®)
- Final Disposal
Liquid Waste Treatment
Evaporation Technology

• Industry Leading Evaporation Solutions
• Evaporation Technologies
  - Falling film
  - Natural circulation
  - Rising film
  - Forced circulation
  - Enhanced Forced Circulation (turbulence enhancers for highly viscous feed)
• R&D Capabilities
  - Analytical Testing
  - Bench-scale Testing
  - Mini-Works
  - Pilot-scale Testing
• Waste Water Treatment in Nuclear Industry
  - Demineralizer regeneration waste
  - Borated water blowdown
  - Turbine building blowdown
  - Laundry waste and boron recycle concentrators
Solid Waste Treatment
Ellesmere Port - High Temperature Incineration

- **100,000 tons/a capacity**
  - EPR 10 permitted
  - Hg abatement in place (100s ppm)
  - Waste acceptance:
    - Solid packaged wastes in range of containers up to 210 ltr drum
    - Bulk liquids (>20 ltr) drums and IBCs for direct injection into kiln
    - Sludges in drums and IBCs via shredder

- **RadWaste capabilities**
  - Monthly disposal cap.: 7,2GBq
  - No physical volume limit
  - Surface dose rate < 20μSv/hr
  - Able to process range of waste streams:
    - Sludges
    - Scales
    - Pig Wax
    - PPE/Packaging
    - Aqueous material
Solid Waste Treatment
Ellesmere Port – Shredding, Mixing and Pumping

Inside the Shredder
Can process steel drums, IBCs, fibre drums and bulk bags

Mixing Chamber
Ensures homogeneous stream of waste entering kiln

Feed Conveyor
Suitable for 205 ltr drums, IBCs and 1 m³ bags

Pump
Delivers 25kg ‘slugs’ of waste into kiln
Radioactive Waste Stabilization
Cementation

- Design, Build and Operation of Industrial Units
  - Conceptual design for fixed or mobile units
  - Multiple references in radioactive wastes (from VLLW to MLW)

- Development of Adapted Solidification Formulations
  - Cement based
  - Special additives
  - Extensive Know-How from hazardous waste management

- Quality and Conformity Control of the Final Waste Prior to Disposal
  - Final repository specifications quality check
Waste Vitrification Technology
GeoMelt®

• **Melter Systems**
  - In-Situ vitrification technology ideal for soil, solid wastes and debris
  - In-Container vitrification technology ideal for waste streams
  - Unique comingling of wastes to utilize glass forming capabilities of one stream to stabilize other

• **Technology Maturity**
  - >26,000 tons of glass and to decades of projects
  - Nuclear, hazardous and mixed wastes
  - Facilities in US, Japan and UK

• **Project examples**
  - Hazardous wastes operations in Japan since 1990s
  - Pu soil stabilization in Australia
  - Radwaste at Sellafield, UK
  - Demonstrating application of GeoMelt technology to treat reactive metals
Tens of thousands of cubic meters of ILW waste expected from decommissioning of the Sellafield site (UK’s Largest Nuclear Facility)

Site Operator evaluating options to baseline approach of grouting wastes due to volume increase and limitations of grout

Identified GeoMelt® as a viable candidate due to its flexibility, effectiveness and robustness (capability to simultaneously treat heterogeneous waste streams)

Kurion partners with the UK’s National Nuclear Lab to deploy GeoMelt on the Sellafield Site

System installation being completed in NNL’s “one of a kind” Central Laboratory Facility.

Radioactive commissioning completed in July 2016
Sellafield Waste Stream Demonstration

Test 1 - PCM Waste

Simulated crushed 55-gal drums being loaded into overpack and grouted

Simulated PCM waste and metal debris prior to melting

Test 2 - Pile Fuel Cladding Waste

Magnesium rods / simulated Pile Fuel Cladding Wastes

Filter Media Materials

Sand and Clinoptilolite

Simulated Pu contaminated materials
Sellafield Waste Stream Demonstration cont

- Fuel skip being lifted out of B-30 storage pond
- Surrogates being staged in skip
- Simulated skip loaded into ICV vessel
- View of waste processing
- Inner ICV liner post-treatment inspection
- Refractory and product during dismantling
Performing demonstration melts for reactive metal treatment of radioactively contaminated materials

Scaling up demonstration melts from crucible level to Kurion’s engineering scale GeoMelt® In Container Vitrification (ICV)™ system

Using the Sellafield approach of demonstrating treatment objectives met by first treating non-radioactive simulates and then progressing to the actual waste

Provides “hands off” treatment (deactivation) of reactive metal in a controlled environment in a predictable manner
Waste Vitrification Technology
Modular Vitrification System (MVS®)

• Melter Systems
  - Single-cycle hot-wall inductively heated in-container system
  - Heating range from ambient to 2000°C, providing only in-class flexibility to melt below volatizing temperature of many isotopes or at very high temps for high waste loading

• Technology Maturity
  - Bench scale system in operation since 2011 and Engineering scale since 2012
  - 100 tests Fukushima and Hanford Tanks waste simulants
  - TRL6 for Fukushima, Hanford and INEL Calcine wastes

• Project Examples
  - Continuous development: MVS® simulant testing in Richland, WA
  - Demonstration waste and storage facility concept (confidential customer)
Radioactive Waste Storage or Final Disposal
From Design to Operation

• **Radioactive Waste Repository Operation:**
  - Operation of VLLW final disposal facility
  - Operation of VLLW intermediate storage
  - Operation of LL-LLW intermediate storage
  - Radiation protection and quality control

• **Storage Design**
  - Over 40 years of experience of disposal facility design and permitting within the VEOLIA Group

• **Waste Logistic**
  - Container logistic
  - Sorting
  - On-site solidification

• **Safety and Environmental Monitoring**

• **Post-operation Planning**
Radioactive Solid waste management
- Client: CIRES – ANDRA France
- Operation of the VLL radioactive Waste disposal facility
- 35 to 40 people on site, depending the activity
- Renewed mid 2015 for 7 years
- Operation (and Maintenance) from the different units and equipment
- Collection and sorting building
- LL-LLW temporary storage building
- Railroad terminal operation and transportation to the storage facilities
- Quality and conformity control unit operation

Radioactive liquid waste management
- INB 35 – CEA Saclay
- Since 2009, Renewed in 2015
- Commissioning, start up and plant operation
- Maintenance of the nuclear liquid waste treatment unit
- Process optimization and plant works
- Production of solid drums for the ML Waste storage unit
- Storage tanks,
- Evaporation and condensation unit,
- Chemical pre-treatment unit,
- Stabilization unit.
- 30 people on site

Nuclear Test Area, Geomelt
- Maralinga, Australia
- 11 burial Pits treated
- 2-4 kg of plutonium treated
- Off Gas collection Treatment
- 500 ton vitrified
- Pu retention for Pu>99.9%
Solving Challenges is our Core Competency

- Commitment to Customer satisfaction
- Demonstrated Performance in high-risk waste environments:
  - Delivered >200 custom Robotic-Remote Systems over two decades
  - Ion Exchange expertise (>10 M Ciures of Cs and Sr removed at Fukushima)
  - >26,000 tonnes vitrified over two decades of remediation projects
- Discriminating solutions:
  - Multiple First-of-a-Kind Technologies Deployed and Matured
  - Modular System/Factory Quality Deployments
- Customer Partnerships