［Format 2］

| Technical Catalog | |
|---|---|
| Category | Airborne contamination sensor |
| Title | Depth Evaluation of Entrained Products (DEEP) |
| Proposed by | Create Technologies Ltd & Costain Group PLC |

１． DEEP is a sensor analysis software for analysing contamination. DEEP can distinguish between surface contamination and internal / absorbed contamination. The software measures contamination depth by analysing distortions in the gamma spectrum. The method can be applied to data gathered using any spectrometer.

Because DEEP provides a means of discriminating surface contamination from other radiation sources, DEEP can be used to provide an estimate of surface contamination without physical sampling. DEEP is a real-time method which enables the user to generate a large number of rapid contamination assessments- this data is complementary to physical samples, providing a sound basis for extrapolation from point samples. It also helps identify anomalies enabling targeted sampling startegies.

DEEP is compatible with small airborne spectrometer/ processor combinations, such as that proposed by the ARM-U project – please refer to the ARM-U proposal for more details of the air vehicle.

**Figure 1: DEEP system core components are small, light, low power and can be integrated via USB, serial or Ethernet interfaces.**

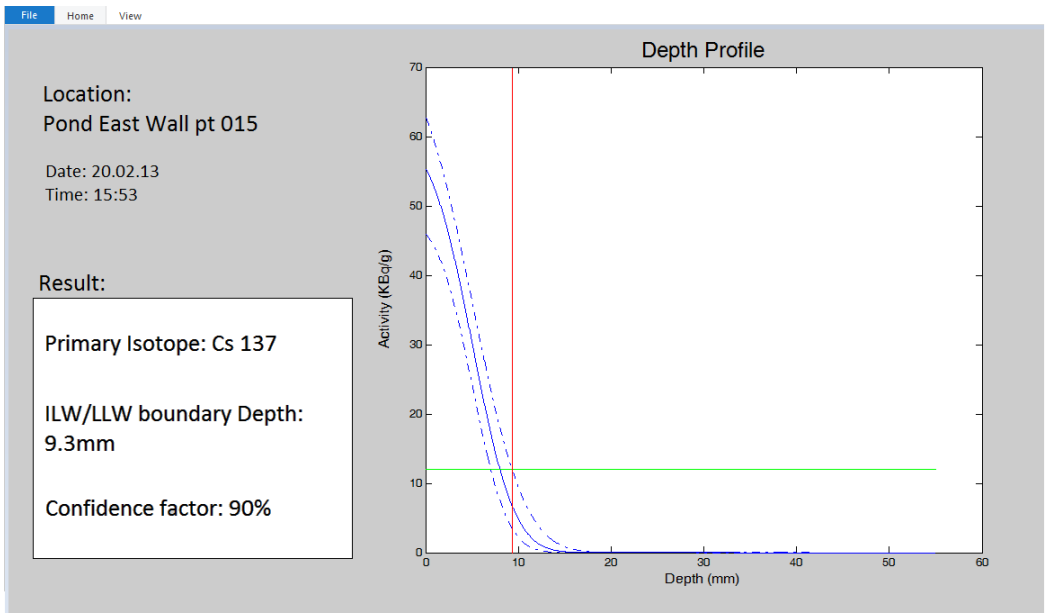



**Figure 2: DEEP prototype software**

## 2． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Create technologies is a specialist R&D firm with a focus on imaging and sensing in the nuclear industry. Createc has developed and delivered several novel nuclear technologies, including the N-Visage gamma camera system.

Costainis a leading UK construction and civil engineering firm with almost 150 years of history. Since the mid-90"s Costain has come to be recognized globally for its iconic infrastructure developments. It is currently one of the biggest suppliers by contract value to the UK nuclear market.

## 3． Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

D:EEP is designed specifically for use in nuclear applications. Its small size and weight and easy-to-integrate nature make it suitable for use on robots and unmanned air systems, particularly ARM-U. The unique feature in this application is the ability to replace or augment dust sampling, by measuring surface-emitted radiation independently of other sources such as scatter and deep/shielded sources.

## 4． Necessary technologies to be developed (Example)

DEEP is an ongoing development project funded by Createc and Costain.

It may be necessary to do additional calibration to for the specific isotopes at Fukushima.

The system would need to be integrated into a mobile platform (it is currently being physically integrated with the ARM-U project). It may be necessary to adapt the sensor to the high dose rates.

## 5． Notes

DEEP is a joint development by Createc and Costain Limited. The system could potentially be made commercially available as a service, as equipment, or as knowledge transfer.

［Format 2］

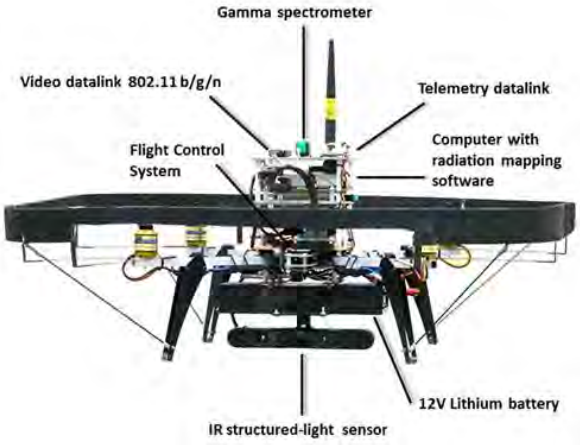
| Technical Catalog | |
|---|---|
| Category | Traveling mechanism (including the working mechanism and measuring device) |
| Title | Airborne Radiation Measuring and Mapping UAV (ARM-U) |
| Proposed by | Blue Bear Systems Research Ltd and Create Technologies Ltd |

1． Description of the Technology (Features, Specifications, Performance Capability, etc.)

A small battery-powered rotary (quad rotor) Unmanned Air Vehicle (UAV) providing Vertical Take-Off and Landing (VTOL) and hovering capability, demonstrating manoeuverability in confined spaces. The UAV is fitted with onboard sensors and computer with N-Visage™ software to:

- Produce a 3D map of the survey area
- Measure the contamination on each surface in the 3D map
- Determine the dose rate at every point in the map

The UAV is remotely piloted by an operator using video from an onboard camera. A data link between the UAV and operator (which could use installed WiFi) provides video and telemetry data. The Flight Control System (FCS) enables easy remote operation of the vehicle in non-Line-of-Sight conditions.




| Item | Specification |
|---|---|
| Dimension (H, W, L) | 290 x 500 x 500mm |
| Weight | 2 kg |
| Propulsion | 3s-6000mah 12V Li-Po battery |
| Camera | Camera with Field of View of 60x45 degrees |
| Radiation sensor | Cadmium Telluride gamma spectrometer |
| Endurance | Up to 15 minutes |

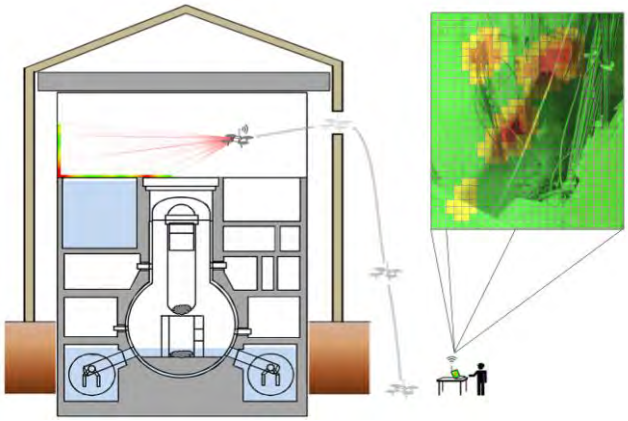


Figure 2: Quad rotor UAV with integrated radiation mapping payload (top). Removable cover not shown. Concept of operations (bottom).

2．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

The Create Technologies Ltd N-Visage™ software is in use at Sellafield and other UK nuclear sites.
The Blue Bear Flight Control System is proven technology used on several military UAV programmes including the US Army Long Endurance Multi-Intelligence Vehicle.
Blue Bear and Createc are involved in a UK government funded programme to integrate N-Visage™ software with the quad rotor UAV for field trials and demonstration at the UK National Physics Laboratory using real gamma sources.

3．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

| **Applicable issue** | **Applicability** | **Remarks and reason** |
|---|---|---|
| Usability in a radioactive environment | Yes | N-Visage regularly used in nuclear industry.<br>Quad rotor subject to testing |
| Dosimetric measurements | Yes | Dose rate and gamma spectrum |
| Collect and carry dust sampling equipment | Future | Modification to current payload required. N-Visage provides non-contact contamination measurement. |
| Access to roofs, ceilings, walls and equipment | Yes | Vertical flight and hovering capability |
| Application to narrow spaces (600mm) | Yes | Outer diameter 500 by 500mm |
| Self-localisation in complex working environment | Yes | Use of structured light sensor for 3D Simultaneous Localisation and Mapping (SLAM) |
| Dispatch of operation engineers | Yes | Dispatch to Fukushima Daiichi Nuclear Power Station is possible. |

4．Necessary technologies to be developed (Example)

- Adapting the vehicle to collect dust samples.
- Environmental testing, radiation hardening for high-dose fields (500 mSv/h and up).
- Further refinement based on results of field trials.

5．Notes

Future upgrades could include :

- Automatic collision avoidance of objects with minimal operator input by the integration of the 3D mapping sensor with the onboard guidance, navigation and control algorithms.
- Operation requiring minimal operator input, operator would perform monitoring role.

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Measurement Device |
| Title | ARM system |
| Proposed by | Interface Analysis Centre (University of Bristol) supported by National Nuclear Laboratory (NNL) |

１． The ARM system is the world's first autonomous low altitude aerial radiation detection device. Integrating lightweight gamma spectrometers with an unmanned aerial vehicle (UAV) it allows the operator to accurately assess a radiological hazard at a remote and safe distance, providing real-time information on the source isotopes, intensity and location of the radiation.

The low weight, size and cost of the instrument combined with its capability for performing high spatial resolution aerial surveys makes it highly applicable and versatile for deployment across the nuclear industry. Example applications include:

1. Rapid disaster response monitoring of nuclear events, providing real-time data on spread, source and intensity. This could range from site incidents to terrorist events.
2. Routine monitoring of nuclear sites (internally and externally), mining operations and oil and gas facilities.
3. Environmental monitoring for site decommissioning.
4. Environmental monitoring of war zones for spent depleted uranium munitions.

Over a period of twelve months the instrument has been developed from a concept to a prototype with proven capability. Field demonstrations of the ARM prototype were performed at a Uranium mining site in the Banat District of southwest Romania. Data gathered by the ARM system was validated against traditional surveying methods. The prototype demonstrated the ability to produce

accurate, high resolution radiation maps at a rate much greater than conventional techniques.
Working closely with interested parties over the next 6-12 months, the ARM system will be further validated on sites in the UK for both routine monitoring and disaster response applications.

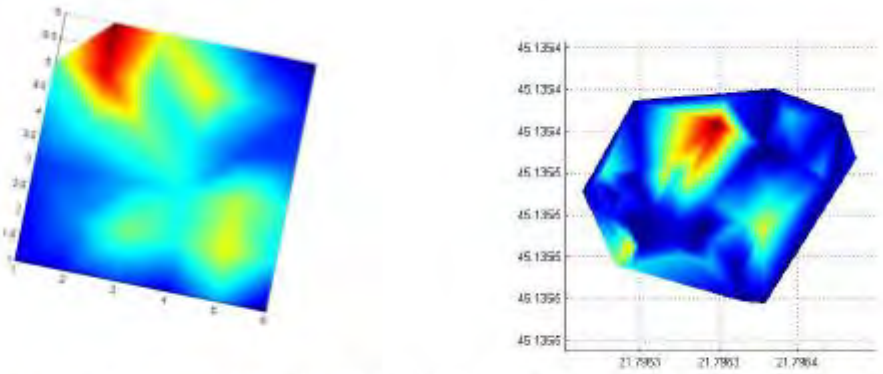
The remote control vehicle used in the prototype is a multi-rotor (6) hexacopter, which provides flight times up to 30 minutes. The current system is able to perform differential GPS to determine spatial X, Y position to within +/- 10 cm. The altitude (Z) of the ARM system is determined using differential air pressure analysis. This entails comparing starting ground air pressure with traveling vehicle air pressure, such that vehicle Z position is determined to within +/- 1 cm. During flight, X,Y,Z data is logged every 500 ms and recorded to an onboard mircoSD card or can be transmitted to a remote operator. The vehicle also possesses functionality to fly from GPS waypoint to waypoint with controllable travel speed altitude and hover duration. It is also able to carry payloads of up to 1 kg on a gyroscopically stable mount, and is controllable over good distances (≤7km). All this technology together provides the ability to acquire gamma radiation spectra from any single location for periods of several tens of seconds to minutes.

２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

The Interface Analysis Centre (IAC) at the University of Bristol has a long history of specialising in the application of a variety of analytical techniques to the study of various types of nuclear materials.
Having spun out of the Central Electricity Generating Board's Berkeley Nuclear Laboratories in 1989, exotic and nuclear materials of all types - including fuel, reactor materials and waste - have been of key concern. Since the late 1990s the IAC research programme has been strongly aligned with the electricity generation industry, especially nuclear. Research has always been focused on the study of materials from a standpoint of in-life environmental and ageing effects. Significantly this has included the development of devices (probes, instruments, detectors etc.) for the analysis of materials both in the laboratory and in-situ. Our research team is well trained and experienced in conducting field investigations in radioactive areas, including monitoring and mapping of radiation. This includes the use of standard personal protective equipment for challenging environments including the use of full respirator equipment. The ARM system is just one example of innovation arising from our research into developing detection systems for monitoring radioactivity in the environment.

In developing the ARM system in 2012 we have conducted several key feasibility investigations at two contaminated uranium mining sites in the Banat District of Southwest Romania. Working within

this environment provided a unique opportunity to demonstrate the capabilities of ARM system, with two highlighted examples including the detection of radioactive sources placed within an engineered geo-referenced grid environment and a survey of a discreet area of the contaminated mining site.



*A comparison between recorded radiation intensity between a handheld survey (left) and an ARM system survey encompassing the same area (right).*

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

The ARM device, as an aerial platform gamma spectrometer, is very applicable to activities at Fukushima. The system provides the capability to provide highly detailed radiation maps of the environment, capable of detecting localized radiation sources only a few tens of centimeters in extent. The detector arrays are able to be positioned in multiple orientations to provide directionally sensitive spectral data from floors, walls and ceilings of the power plant. The device is simultaneously capable of relaying a live video feed of the area to the remote operator, who may be situated up to 7km from the region of interest.

The ARM system is ideally suited to immediately provide external inspections and radiation surveys of structures at the Fukushima Daiichi nuclear power plant. With modifications to the communications systems, it would be possible to use multiple ARM systems for surveying inside structures (rooms, corridors etc) by relaying telemetry/control data from UAV to UAV within line-of-site.

The manoeuvrability and speed of the device, coupled with its real time imaging and activity measurement capability mitigate the effect of high dose rates on the system, by allowing peak doses to be avoided. There is also the opportunity for increasing the radiation hardness of the electronic systems.

| Applicable Issue | Applicability | Remarks |
|---|---|---|
| Confirm the situation of the environment using camera vision | YES | The ARM device provides real time remote visual imaging |
| Obtain dosimetric measurement results of the environment | YES | The ARM device has validated operating experience for making high resolution activity measurements |
| Collect and carry dust sampling equipments | DEVELOP | The payload capability of the ARM device is consistent with carrying lightweight sampling and retrieval apparatus |
| Usability in a high-humidity environment | YES | The primary functional components of the ARM device have operating experience in high humidity environments relating to high temperature ambient conditions, although further proving would be required in relation to temperatures up to 60 ºC |
| Investigation inside the PCV | DEVELOP | The mobility and stability of the ARM device, in concert with its real time activity and imaging feedback make it ideally suited to locating and characterising material within restricted areas |
| Investigation of position/status of fuel debris inside RPV | DEVELOP | Additional systems for close quarters location and collision avoidance could be applied for confined space entry. |

４． Necessary technologies to be developed

There are numerous areas for further development of the ARM system to optimize it for use in Japan. The following are considered to be key:

- Translation of the ARM detector technology for use on underwater remotely operated vehicles (ROVs).
- Development of automated collision avoidance for flying inside buildings.
- Improvement of the battery system to provide longer flight times.
- Development of multiple ARM units to coordinate relayed communications and surveillance of inaccessible places.
- Switch from CZT to diamond based detectors to provide improved hardiness to detector degradation in high radiation environments.

5． Notes

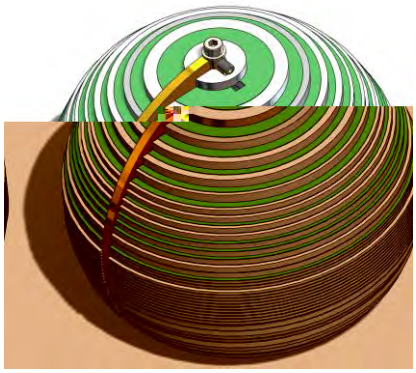

Images of (left) the ARM system in flight at an abandoned radiologically contaminated building in Romania and (right) site radiation dosimetry survey data.

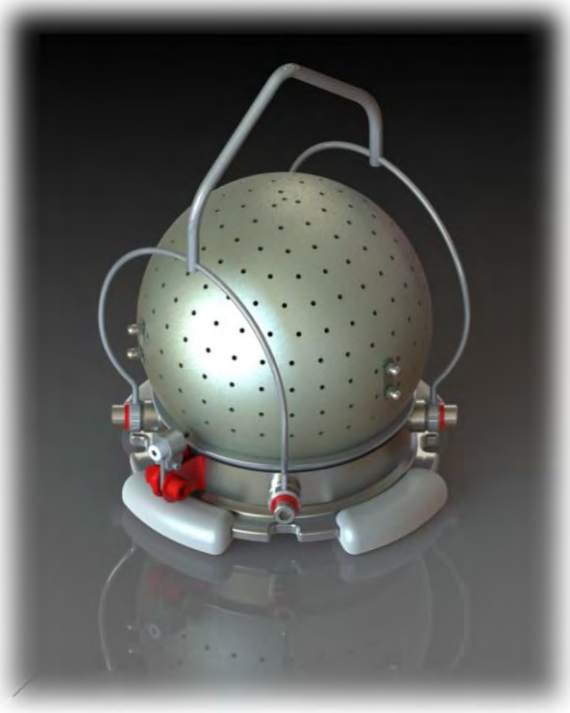
［Format 2］

| Technical Catalog | |
|---|---|
| Category | Measurement Device |
| Title | RadBall® |
| Proposed by | National Nuclear Laboratory (NNL) |

１． Description of the Technology (Features, Specifications, Performance Capability, etc.)

The RadBall® is a passive, easily deployable gamma radiation hotspot detector that can withstand very very high radiation levels of up to 1000 Sv/hr. It is made up of a gamma radiation sensitive core (below left) surrounded by a collimation device (below right). The collimation device preferentially allows the gamma radiation through the holes and when the radiation interacts with the core, the core changes colour making visible „radiation tracks". The direction of these tracks relate to the direction in which the radiation hotspot lie, and the amount of colour change relates to the total dose that track has deposited within the RadBall®. When greater than one RadBall® is deployed, the location of the hotspots can be determined and their dose rate can be calculated.





The RadBall® has a total dose detection range of 50 mSv – 40 Sv which allows dose rates up to 1000 Sv/hr for quick deployments. The deployment time is dependant on the area size and hotspot dose rate expected to be located. Full post deployment analysis < 1 day.
The RadBall has a diameter of 14cm and height of 15cm. The device has a removable lifting mechanism. With the lifting mechanism attached, the total height of the RadBall is 21cm. The RadBall® has a weight of 13kg. Each RadBall® maps a 3-4m radius area about its location. It is highly recommended that more than one RadBall® is deployed per area to allow for exact source location.

A RadBall® deployment is a 6 step process.
1) Deploy the RadBall® at a known location and of a known orientation (the RadBall® comes with a clear marker [which can include a laser] which is pointed in a known direction. If the RadBall® cannot be seen directly by the deployment method, photographs of the deployed RadBall® or orientation via a ROV can be used).
2) Leave the RadBall® for a pre-determined period of time (deployment time is determined on dose approximations and anticipated detection limits. It should be noted that the RadBall® must have a deployment time significantly longer than the time it takes to move it in and out of position)
3) Remove the RadBall® from the area
4) Dismantle the RadBall®
5) Analyse the data on the film
6) Present the results

２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Successful trials in both the UK and USA using both remote and manual deployment methods.
Recent work consisted of characterising a room into Low Level Waste (LLW) and Intermediate Level Waste (ILW). The RadBall® performed very well and allowed a plan for each item to be disposed of in the most appropriate and cost effective way. The RadBall® has recently been tested with point sources of hundreds of Sieverts per hour with an ambient background dose at the RadBall® location of up to 75 Sv/hr.

３． Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

The RadBall® is perfect for understanding hotspot size and locations for areas which are accessible remotely or manually. The RadBall® has a wide detection range therefore it is applicable for a range of dose hotspots.

| Applicable Issue | Applicability | Remarks |
|---|---|---|
| Usability in a radioactive environment | YES | Passive, and non-electrical therefore highly radiation resistant. |
| Usability in a high-temperature environment (60°C) | YES | No previous experience at temperature but the system is stable to 40°C and the temperature can be accounted for at 60°C. |
| Usability in a high-humidity environment (60°C) | YES | RadBall® has been used under water in the USA. A protective casing was made for full submersion however high humidity will have no effect on the RadBall®. |
| Radiation hotspot mapping in plant areas other than the RPV and PVC (e.g. small cell, operator floor) | YES | RadBall® has a wide range of application due to its wide range of dose rates it can detect. To minimize deployment time, RadBall® is particularly applicable for high ambient dose rate areas. |
| Investigation of position/status of fuel debris inside RPV | YES | RadBall® may require re-design to fit into access areas. |
| Investigation inside the PCV | YES | RadBall® may require re-design to fit into access areas. |

4．Necessary technologies to be developed (Example)

Deployment systems design for specific uses.

5．Notes

RadBall® flyer and case study attached.

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Remote Inspection System |
| Title | Modification of commercially available ROVs for the use in high radiation areas |
| Proposed by | AMEC |

１．Description of the Technology (Features, Specifications, Performance Capability, etc.)

AMEC has several years experience operating observation class ROVs around nuclear facilities and as such are aware of no commercially available units capable of operating within the size & ration constraints present in this facility.

We propose the modification of either the video ray pro4 or SeaBotix LBV150-4 chassis to remove the electronics from the vehicle, driving the system through direct voltage control, space provided by removal of the electronics package will be used to fit a radiation tolerant camera system.

Deployment and retrieval will be conducted by a removable rail system fed through the access port.

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Operation of ROVs within the Sizewell refueling cavity

Operation of ROVs within the various nuclear fuel ponds

Operation of crawler system within fire damaged plant

Operation of ROVs in water intake pipes

Development and operation of submersible remote intervention packages for Sellafield fuel ponds

Debris retrieval from damaged ponds using ROV system

Development of ROV tooling for the removal of sludge from fuel ponds

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

Past experience operation ROVs in nuclear environments

４．Necessary technologies to be developed (Example)

Production for a secondary control box to house the vehicles removed electronics.

Tests on the new camera system and its effects on the vehicles buoyancy.

５．Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Inspection Equipment, Underwater Equipment, Robotic Device, Snake Robot, Small Manipulator |
| Title | Snake Robots for Underwater Investigation |
| Proposed by | Dr Howie Choset |

１． Description of the Technology (Features, Specifications, Performance Capability, etc.)

Carnegie Mellon has been developed snake robots for the past 16 years. Typically, each robot contains 16 joints (degrees of freedom), each rotated 90º with respect to each other to allow for true three-dimensional motion (Figure 2). The current generation of the lab's robot is dust-proof and water-resistant, and can be made to swim by inserting the robot in a waterproof skin. Each module of the snake robot contains a single, efficient high-voltage DC motor, a metal-gear drive train, built-in inertial sensing, two-inch diameter aluminum housings, and a connectorized interface. All control and communication occurs on a robust two-wire serial bus. Power is supplied through a tether. The next generation snake robot, currently under development, will be completely water proof without the need for an exterior skin.

The robots have demonstrated the ability to swim, in both a tethered and untether configuration.

The snake robots have a uniquely small cross-section such that they can navigate through tight spaces and work in complex and narrow environments. They swim by changing shape and executing sinusoidal gaits, reducing turbidity and unwanted disturbance to the surroundings. Additionally, given the snake robots' high degrees of freedom, the snake robots can potentially wrap around objects such as pipes to anchor themselves in a stable location. Once the tail of the robot is wrapped around a pipe or otherwise anchored, the robot can maneuver its head to view objects from multiple vantage points. The robot has been able to demonstrate such ability by transitions from the ground to wrapping itself around a flagpole, climbing to the top of the flagpole, and then manipulating the head to look in the desired direction. Our snake robots are unique in this capability, which may be useful for inspection in underwater environments such as the flooded reactor, or performing manipulation tasks underwater.

http://www.biorobotics.org

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

The robots have been deployed in multiple power plant environments, including deployment into a turbine, into a piping network, and inside and around multiple Heat Recovery Stream Generators (HRSGs). HRSGs represent a cluttered environment of multiple pipes, to which the snake robots are well suited.

The robots have additionally been deployed in a variety of non-plant real world environments outside of the lab. The robots have been deployed inside a mine, inside a collapsed building environment at the Disaster City facility in the United States, been deployed inside of underground storm water pipes, inside of culverts, through caves in Egypt for archaeological purposes, and even inside of a prairie dog tunnel network.

Related snake robots developed by the Biorobotics Lab have been used for manufacturing inside confined spaces such as aircraft wing boxes, and a smaller snake robot mechanism has been developed for performing minimally invasive surgery.

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

The robots are able to swim, the robots are able to climb on pipes or other structures, and the robots are able to locomote through cluttered environments. The robot"s current 2-inch (52 mm) diameter could be useful for the underwater environment in Fukushima.

The robots have not been hardened for radioactive environments.

４．Necessary technologies to be developed (Example)

Technical challenges include communications to the robot while underwater if a tether cannot be feasibly used. Developing intuitive operator controls for navigating to underwater waypoints or wrapping its body around pipes or anchor points could enhance the robot"s ability to perform the required inspection tasks. The next generation of robot is designed for submersion to depths of at least 30 feet; testing remains to be conducted to determine exactly how deep the new robots can be submerged.

５．Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Research and Development |
| Title | Research and Development |
| Proposed by | Forth Engineering |

１．Description of the Technology (Features, Specifications, Performance Capability, etc.)

Design and development of technical solutions and machinery, inspection systems and remote operated vehicles mainly for use in the nuclear industry. Specializing in underwater deployment in nuclear pod size reduction through innovative methods, cropping, plasma and laser. The equipment is developed using real-time simulator in our replica nuclear ponds where operator training can be perfected before live deployment on plant.

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Trade mission to Japan and Korea November 2012

Large experience working with Sellafield in particular FGMSP

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

Large

４．Necessary technologies to be developed (Example)

Remote Deployment of tooling into highly active areas.

５．Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Remote handling and sensor technology |
| Title | Snake-arm robots |
| Proposed by | OC Robotics |

１．Description of the Technology (Features, Specifications, Performance Capability, etc.)

OC Robotics design and builds snake-arm robots designed specifically for high hazard environments.

These robots have many joints that enable them to navigate by nose-following within confined spaces. They can carry a significant payload in order to conduct a range of tasks including cutting and handling as well as inspection.

OC Robotics has recently completed a project for a commercial customer for a snake-arm operating in 100% humidity at elevated temperature, increased pressure and mud. The task was water jetting and inspection. Further details will be released in April 2013.

We have completed real projects for nuclear utilities in Europe and Canada.

We are also working with the UK National Nuclear Laboratory and Sellafield to develop a long reach manipulator that is able to conduct a range of decommissioning tasks in high hazard spaces. OC Robotics is leading a £8m program that will develop this technology – announced March 2013. OC Robotics is aware of the specific challenges posed by the PCV and RPV environment. We are targeting a snake arm that has an articulated length of 4.5m (much longer when integrated with other existing technology such as booms or telescoping technology); payload of 15kg; degrees of freedom 32; diameter 150mm; repeatability <10mm. The arm will be designed to operate in air and in water.

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Systems delivered to: Ringhals NPP, Pickering NPP

Other nuclear contracts: Areva, Sellafield, EDF, Salvarem, ITER, NNL, AMEC, NDA

Other contracts: Oil&gas sector, Construction sector

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

OC Robotics has conducted initial work for Hitachi and is aware of the significant challenges involved in working within the Torus Room, PCV and RPV.

４．Necessary technologies to be developed (Example)

The Torus Room, PCV and RPV are EXTREMELY challenging environments. We understand these challenges because we design and build robots for similar conditions for other customers. The technical challenges that remain include: further increases in reach with useful payload (to do work as well as inspect).

５．Notes

Dr Buckingham is speaking LANE 13 in Yokohama on 23 April 2013 – presenting working on laser cutting delivered by snake-arm. http://www.ilt.or.jp/event/lane13/

Videos and case studies are available at http://www.ocrobotics.com/file-downloads/videos/

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Sensing and monitoring device |
| Title | Avexis |
| Proposed by | National Nuclear Laboratory (NNL) and University of Manchester |

１． Description of the Technology (Features, Specifications, Performance Capability, etc.)

This is an early stage technology where a swarm of mobile sensor nodes is used to map a pond where individual nodes are used for exploration, sensing, communications, localisation, propulsion, and control and the whole System can be deployed in swarm plus 'shore'- based base-stations / recharge-stations.
The technology is based on wireless sensor networks (WSN) which consist of collections of 'nodes' containing sensors, communications transceivers and an embedded computer system. Nodes organise themselves into a computer network, which is used to send sensor readings to a base station.

２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

A demonstrator system has been developed and is concerned with measuring the conditions within nuclear waste storage ponds, providing crucial information that will enable a carefully planned material removal and disposal programme to be carried out. The system was tested at NNL Workington and in local swimming pools.
- A large amount of data was gathered and are being analysed to enable tuning of the communication system parameters
- Position estimates with an accuracy of 5cm were obtained

３． Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

Advantages are:
– Cost per vehicle: The vehicles have been designed using low-cost off-the-shelf components so that they can be 'expendable'
– Size: The nodes are some of the smallest autonomous underwater vehicles currently available which allows them to be used in confined spaces
– Manoeuvrability: There is a high level of manoeuvrability which will allow the vehicles to navigate in cluttered environments

| |
|---|
| – Functionality: The vehicles are mobile sensor platforms allowing multiple measurements to be taken and the vehicles can collaborate as a networked swarm.<br><br>Key technical challenge would be whether the technology could withstand required levels of radiation. |
| ４．Necessary technologies to be developed (Example)<br>– Technology development<br>– A full demonstrator system |
| ５．Notes |

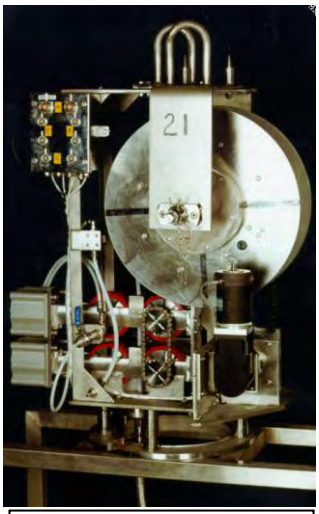
［Format 2］

| Technical Catalog | |
|---|---|
| Category | System |
| Title | Remote Camera Inspection & High Pressure Wash System for recovery of in-cell vessel and pipe blockages |
| Proposed by | National Nuclear Laboratory |

1． Description of the Technology (Features, Specifications, Performance Capability, etc.)

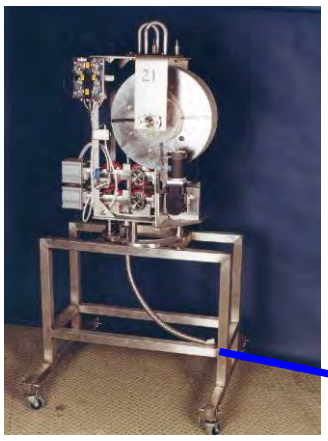
The system consists of a remotely operated deployment and recovery unit which has electrically driven rollers and a reeling drum. Once positioned in cell this device is then used to remotely deploy a 35m long umbilical down the required pipework (down to 50mm NB). The umbilical houses a high pressure jetting hose and the end is fitted with a 30 mm diameter tungsten head which houses LEDs, a miniature camera and the high pressure wash nozzle. The camera and LEDs are completely waterproof and are used for inspection of the pipe internals, blockage material and when aiming the device during deployment.

Once at the blockage site the umbilical is connected to a 350 bar pump and forward and rearward facing jets on the nozzle clear the blockage and scour the walls of the pipe clean. The umbilical is then remotely traversed forward through Highly Active Liquor to clear the full length of Highly Active Solids blockage.



Deployment Unit

A low pressure chemical wash variant of the system was also successfully used on plant several years ago. The modified high pressure jetting variant of the system has recently undergone extensive development trials and been successfully demonstrated on a full scale mock up.



Deployment Unit on transit frame showing camera guide tube

Camera, Lighting and High Pressure Jet Wash Head

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Applied at Sellafield Nuclear Reprocessing Plant UK.

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

System Features

- The low pressure chemical wash variant of the system has been successfully operated on plant to clear blockages and clean pipework.
- The high pressure jetting variant of the system provides fast and efficient unblocking and pipe cleaning capability.
- Fully remote engineered solution providing minimal dose uptake to the operators.
- Fully remote deployment and recovery with no breach of containment.
- Full remote recovery in event of component failure.
- In built redundancy to cater for component failure.
- Deployment with minimal disruption and down time to existing plant.
- Proven as a cost effective method for recovery of plant compared with the alternative solution which would have involved breaking containment, cutting out the section of blocked pipe, and welding in a new section.
- Cameras can be submerged in nitric acid solutions.
- Flexible, versatile solution that has been adapted for other plant configurations and purposes e.g. camera inspections, sampling and flushing.

４．Necessary technologies to be developed (Example)

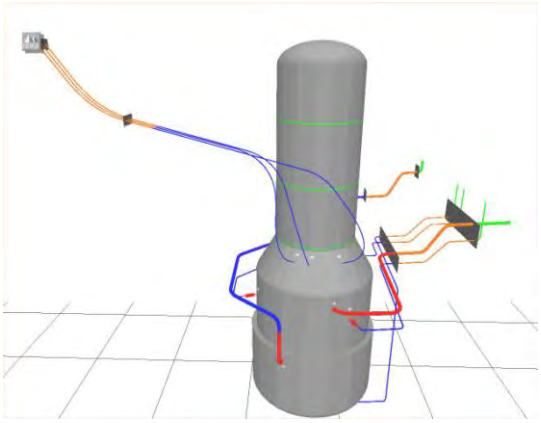
５．Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Measurement Device |
| Title | Remote gamma radiation measurement. |
| Proposed by | National Nuclear Laboratory, UK |

1．Technical details (features, specifications and performance)

Gamma radiation measurement in remote regions using small bore pipework deployment routes. Deployment distance dependant on internal bore of pipework Radiation sensor (GM tube) very small (can be deployed down 20mm bore pipework) and can be integrated onto other inspection tools.



Blue lines = inspection routes used on plant

Radiation measurements of up to 1000 Gy/hr.

2． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

These inspection tools have been used on many applications throughout Sellafield nuclear reprocessing plant (UK).

3． Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

Can access remote locations via pipework. Can characterize radiation in remote applications. Can be added to other inspection tools and applications. The system can be customized for each application. Full design, build, and inspection service available.

4． Necessary technologies to be developed (Example)

Minimal, dependant on application.

5． Notes

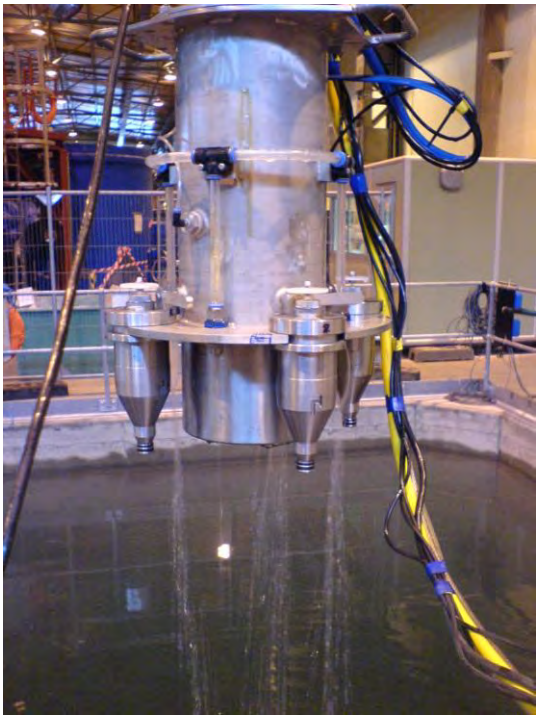
［Format 2］

| Technical Catalog | |
|---|---|
| Category | System |
| Title | Remote Underwater Sludge Sampling System |
| Proposed by | National Nuclear Laboratory |

１． Description of the Technology (Features, Specifications, Performance Capability, etc.)

The NNL designed and built a device to sample the pond sludge and pond liquor and assess the effect of disturbing the sludge in situ. This device was remotely deployed at several different locations from the pond wall to descend to the sludge at the base of the pond. The device was designed to then sink into the radioactive sludge, thereby isolating a portion of it and the over standing supernate liquor. A number of cameras and gauges were fitted to the device to assist in this remote deployment.

An electrically driven rotor was then remotely operated to mobilise the isolated sludge within the mixing chamber and the subsequent activity levels released were monitored by extracting liquor samples before and after the disturbance. In addition, the device had four sludge samplers positioned around the periphery of the mixing chamber to extract solid samples of the sludge for recovery to a laboratory where the chemistry and radiochemistry of the sludge could be assessed.



Underwater Sludge Sampling System

２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Applied at Sellafield Nuclear Reprocessing Plant UK.

| |
|---|
| 3．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges<br><br>• Remote sampling of Sludges |
| 4．Necessary technologies to be developed (Example) |
| 5．Notes |

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Working equipment Underwater |
| Title | Underwater Cleaning and inspection |
| Proposed by | Weda Poolcleaner AB/ Klas Lange |

1. Underwater cleaners: Equipment for removal of sedimentation on floors and walls under water. The cleaners move on the floor (Concrete or sand floor) and a strong on-board pump sucks out the sediment and pump it to a designated discharge point through a hose connected directly on the pump. The cleaner can be equipped with various opotional equipment such as a nozzle with a built-in brush or auger, on-board camera for navigation and inspection.

The specific design of the cleaner will be carried out in cooperation with the user. The deciding factors are normally:

-Size and type of sediment
-tank bottom and wall conditions. Sand or concrete bottoms etc.
-Possibilities to access the tank/reservoir.
-Other client demnds for materials etc.

2. ROV Inspection vehicle: A remote controlled underwater vehicle for inspection of walls and floors in all sorts of conditions. On-board camera allows for recording and positioning inside the tanks.

Equipped with a 100 meter Teflon umbilical, several control functions for settings of depths etc.

２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

The Weda cleaners are widely used by clients like Veolia (water and waste water), Emaar construction (artificial lakes and controls, ECA, Mexico (desalination plants, POSCO, Southkorea (steel production plans).

Within the nuclear field several cleaners are used by Magnox Corporation (UK) for cleaning of holding tanks, Swedish Vattenfall AB (Forsmark plant) for cleaning in reactor tanks.

Electricite de France for several applications within nuclear power stations.

Weda has delivered cleaners for applications within the nuclear sector for more than 30 years. Weda has also established cooperation with Westinghouse specifically for cleaning (removal of radioactive aerosols) in reactor tanks.

３． Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

We need to discuss the specifics around the applications to determine the most suitable basic cleaner and eventual options.

４． Necessary technologies to be developed (Example)

During Wedas more than 30 years in the industrial field we have designed cleaners for almost any type of application. There should be no need to develop new technologies but the design of the specific cleaner is more a question of which technologies to use for this specific application

５． Notes

The basic product that Weda offers are presented on the web page: www.weda.se.

The three most probable cleaners would be the VR-600, the YT-600 and the YT-800.

The cleaner developed together with Westinghouse (U-DEC) is only briefly described under the “news” section on the web site.

We will be pleased to discuss this more in detail and to furnish more details around our products.

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Working Equipment |
| Title | Jaco, low weight multi purposes robotic manipulator |
| Proposed by | Kinova Robotics |

1. Description of the Technology

The Jaco robotic arm is a low weight manipulator that is a perfect fit for robotic mobile platforms.

Features:

-Lightweight and compact modular design

-Carbon fiber structure

-Designed to easily grasp and handle objects

-Designed to be easily modified with custom features

Specifications:

-Total weight: 5,7 kg / Ambient temperature: 0 to 30 °C / Water resistance: IPX2 rating

-Payload: 1,5 kg mid-range & 1,0 kg full-extension / Maximum reach: 90 cm

-Average power under normal use: 40 W

2. Past experience

-Used in mobile manipulation in indoor and outdoor environments

-Used as a human assistant for diverse manipulations

3. Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

-Complete C++ /.NET API giving development flexibility and remote operation capability

-End effector can be easily changed

-Tough design and made for duty

-Can be easily integrated on a mobile platform

-Low weight and power efficient

4. Necessary technologies to be developed

-End effector for specific technical tasks

-Under water coating

-Radiation shield

5. Notes

☐ a research and development phase or ☒ a practical application phase.

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Remote Handling, Cranes, Manipulators |
| Title | Remote Handling and Lifting Systems for Hazardous Environments |
| Proposed by | PaR Systems Inc. |

１．Description of the Technology (Features, Specifications, Performance Capability, etc.)

PaR Systems is a solutions-focused engineering company offering a suite of remote handling equipment and lifting systems designed for hazardous environments; including, manipulators, telescoping masts, cranes, mobile manipulators, end effectors/tooling, and tensile truss/mobile work platform. PaR has supplied these systems for over 50 years to customers all over the world. Examples of our projects and technologies are included in the attached.

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

PaR Systems has supplied and is supplying systems to numerous facilities in Japan. We have delivered contracts for JNFL and JAEA. PaR is currently designing and fabricating a tensile truss system for Fukushima.

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

PaR Systems, partnered with PaR Nuclear (a Westinghouse company), is currently under contract to supply a Tensile Truss system for decommissioning operations in Unit 3 at Fukushima Daiichi. Additional technologies may benefit the decommissioning program at Fukushima such as mobile manipulators and telescoping masts.

４．Necessary technologies to be developed (Example)

Certain applications of the technology may require control system upgrades/modifications.

５．Notes

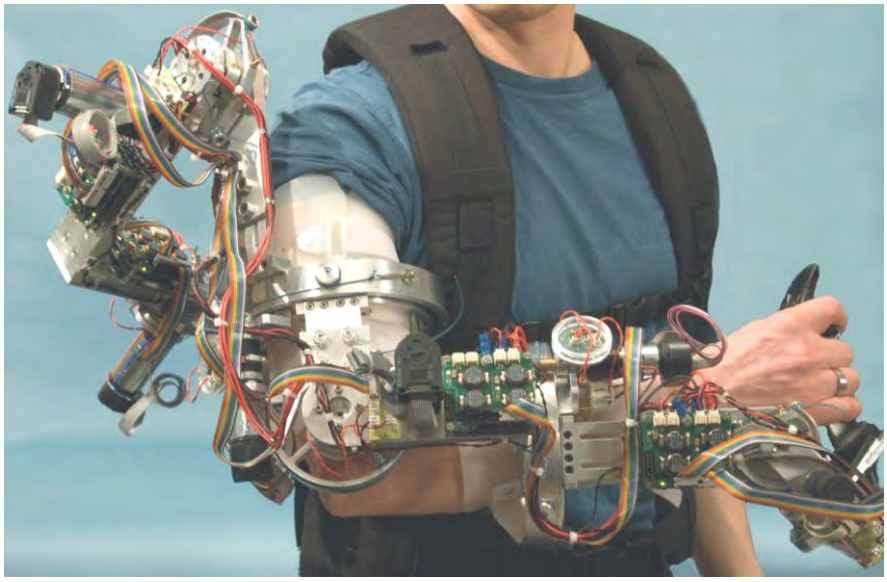
PaR Systems submits the following information to support technology transfer to facilitate remediation activities at Fukushima.

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Working Equipment/ Support Device/ System/ Operations |
| Title | SAM - Force-Feedback Exoskeleton Arm for Robotics Teleoperation and Virtual Training |
| Proposed by | Space Applications Services |

１． Description of the Technology (Features, Specifications, Performance Capability, etc.)

The Sensoric Arm Master (SAM) exoskeleton is a seven degree of freedom portable device able to produce haptic (force-feedback) rendering on the human arm. It can be used as a master interface for teleoperation of slave robots, or to interact with virtual reality environments. This device has been originally designed and implemented for the European Space Agency (ESA) for the teleoperation of future spaceborne robotic arms.



**SAM force-feedback arm exoskeleton.**

By interfacing the human arm, the SAM exoskeleton offers an innovative way to control slave robotic arms for terrestrial applications. Compared to joystick like interfaces, it enables intuitive operations when performing complex manipulations in three dimensions with the addition of force information, reducing at the same time the needs for long training of the operator. The apparatus is especially relevant for :

- Operations requiring human skills, dexterity and expertise;
- Intervention in hostile environment;
- Precise manipulations that do not tolerate errors where the force-feedback information is an added value;

- Emergency intervention in de/un/structured environment.

Based on these criteria, remote manipulations in hazardous environments and crisis civil intervention have been identified as the main fields of applications on Earth.

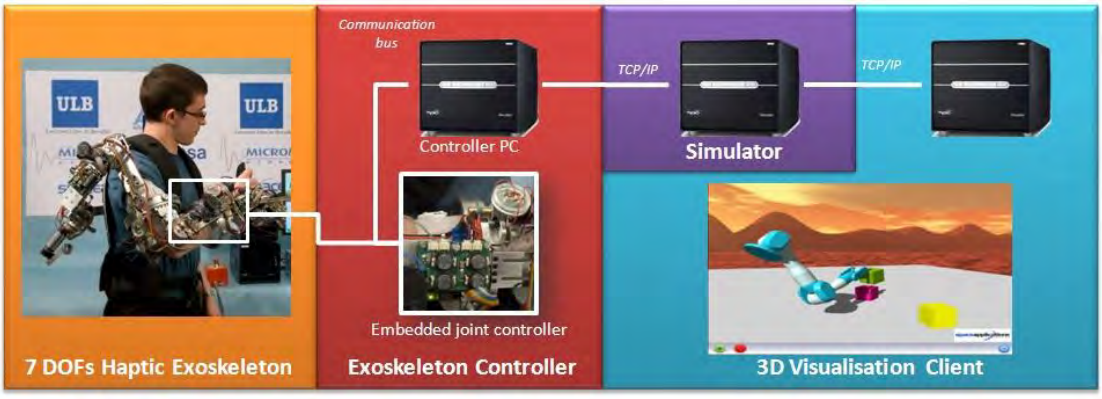
Compared to other force-feedback technologies, like joysticks and desktop devices, the key characteristics and specificities of the SAM exoskeleton are:

- Intuitive manipulation requiring little training for complex tasks operations;
- Multi-point contacts force-feedback rendering on the arm for more immersive haptic experience;
- Large achievable workspace with no singularities;
- Integrated joint design with actuator, position and torque sensors on each articulation for advanced and multiple control strategies support;
- Optimization of the actuation chain to ensure at the same time sufficient haptic feedback and portability, with the possibility of internal gravity compensation;
- On-board integrated conditioning and power electronics;
- Fixed or portable version, for a wide range of applications deployments (control centre, mobile intervention, etc).

The picture above shows a prototype of the master haptic exoskeleton device. Space Applications Services is currently developing an updated industrial version of the device that will be available in the second part of 2013. A radiation hardened version of the system is also under study.

２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

The first prototype of the SAM exoskeleton is currently deployed at the European Space Agency in the Telerobotics and Haptics Laboratory. It currently supports the development of the future space missions that will feature remote robotic arm teleoperation to replace astronaut external vehicular activities or for planetary robot control.




**SAM Exoskeleton deployment for virtual robotic arm teleoperation and testing (ESA EXOSTATION project).**

In the context of the ongoing European research project ICARUS, the SAM exoskeleton is used as a master device for the control of robotic arm excavators mounted on remote unmanned mobile platforms. This setup will be used to support search and rescue activities in the context of large scale crisis management (e.g. earthquake).

Space Applications Services has also relevant experience in other products and services applicable to the decommissioning of nuclear power plants. The company has strong experience in the development of control base stations for mobile robot operations, that includes real-time display of 2D/3D thematic maps and charts, mission control, intuitive speech and touch screen commands, etc.

Space Applications Services has also developed WEAR, a light-weight WEarable Augmented Reality (AR) system for „context sensitive" information visualization and management. By means of an optical see-through HMD and Speech Recognition and Synthesis (SRS), the device allows superimposing 2D/3D virtual features and relevant information such as procedures in the wearer"s field of view. The system is based on hands free operation and includes Vision Based, IMU and GPS sensors for position and orientation tracking.

In addition to developing mission control systems, the company also installs, sets up, operates and manages these systems. The company has trained and provided the Belgian User Support and Operations Centre (B.USOC) team of operators that supports daily operations preparations and on-console operations for scientific experiments on-board the International Space Station (ISS).

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

3.1 Slave Robot Telemanipulation Tool

Due to the presence of high-dose radiation in some parts of the Fukushima Power Plant, the need of remote control and operations of equipments and devices has been clearly identified. The use of the SAM exoskeleton master device can improve drastically the quality and performances of slave robotic arm teleoperation, especially in the context of remote inspection/investigation, sampling collection, manipulation of nuclear waste and repair (e.g. for leakage). While preventing human to be sent in the vicinity of the hazardous environment, the advanced control capabilities of the slave arm allow transporting the human skills and dexterity on site. The SAM exoskeleton intuitive interface will reduce the effort required for familiarizing an operator to the control of the slave robot, will assist him in performing complex operations and will allow him to adapt quickly to unforeseen situations. Considering the number of operations and the time that will be required for the complete decommissioning of the plant and the associated actions (several years), this kind of device can bring a high benefit to the operations in terms of extended capabilities, efficiency, risks reduction, safety improvement and time and money savings.

3.2 Virtual Immersive Training Tool

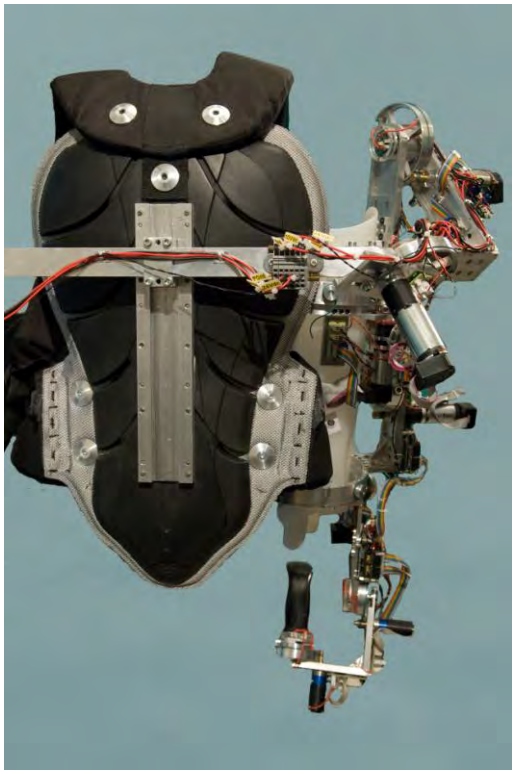
The device is also valuable for performing virtual training on operations requiring human intervention on the contaminated site. Associated with a virtual reality environment simulating the plant facilities and environment constraints, it can be used as a training tool for operators with the aim to reduce the time they spend in the critical zone or to test their reactions under unforeseen or stressful situations. The exoskeleton enables force interaction between the operator and his model in the virtual simulated environment. This tool can also support the analysis and the design of operations procedures by testing several strategies and compare them on quantitative and objective criteria as duration of operations, radiation dose, operator consumed energy, etc.

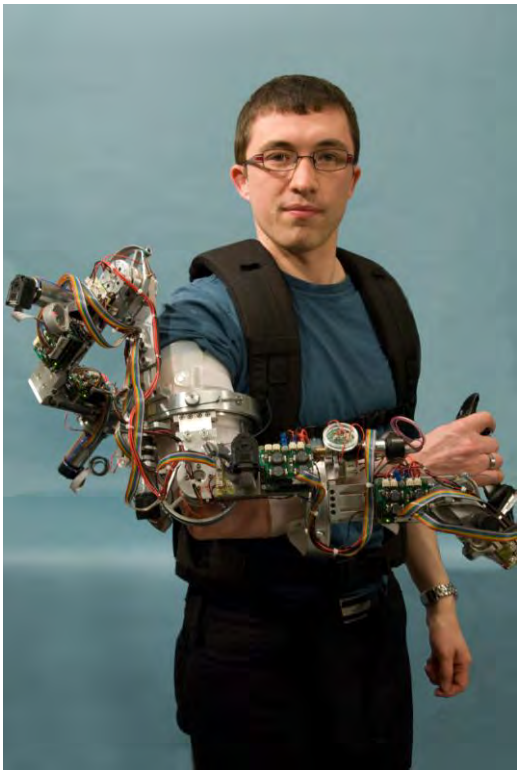
４．Necessary technologies to be developed (Example)

For teleoperation applications, a prerequisite is the deployment of a rad-hard slave robot with a manipulator arm on the intervention site. For virtual training, a virtual environment of the intervention site has to be developed including visual, physics and contacts rendering. In both cases, the exoskeleton can easily be associated with existing platforms, requiring small effort of coupling (interfaces, communications, kinematics). From its strong experience in

robotic platforms, human-machine interfaces and virtual/augmented reality systems (hardware and software), Space Applications Services can propose specific development based on the customer requirements. In addition, the exoskeleton can be associated with other hardware like portable head mounted display (HMD) for more advanced and immersive operations (also deliverable by Space Applications Services).

５．Other Pictures





Youtube Link: http://www.youtube.com/watch?v=pA7lXu4ofmo

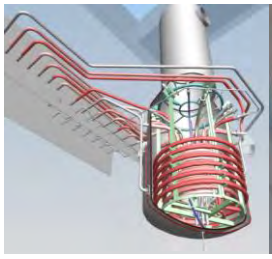
Space Applications Services: www.spaceapplications.com

［Format 2］

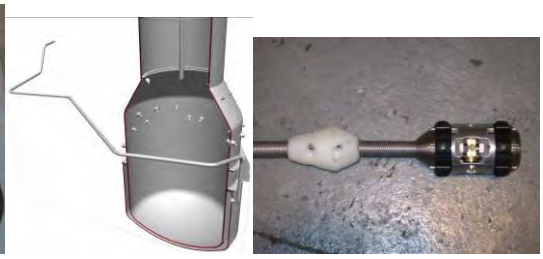
| Technical Catalog | |
|---|---|
| Category | Measurement Device (Thickness survey and CCTV inspection in long pipe routes) |
| Title | Thickness surveys of variable bore pipework and over long distance. |
| Proposed by | National Nuclear Laboratory, UK |

1．Technical details (features, specifications and performance)

Development of inspection “pig” type vehicles to measure the thickness within steam heated austenitic stainless steel coils and steam jacket. Coil pipe route up to 55m long, containing 1.5D elbows, bore change from 70mm (access pipework) to 90mm (measurement region) within Highly Active evaporator. Manual deployment and retrieval. The steam jacket vehicle can orientate the thickness measurement transducer circumferentially 360° and tilt ± 40° to facilitate vessel base thickness measurements. Each heating component is critical to the operational life of the evaporator and so any inspection vehicle development needed to prove to have minimal risk to retrieval. Thickness survey taken using none contact ultrasonic transducers. Fully tested on full scale mock-ups of plant.



Coil inspection route and vehicle



Steam jacket inspection route and vehicle

Each has a CCTV inspection system to assess pipe route during deployment. Each are radiation tolerant to 100 Gy/hr.

2． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

These vehicles have been used on 30 occasions within HA evaporator at Sellafield (UK). Other countries evaluating the technology for use in their plants.

3． Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

Can access remote locations via pipework. Can characterize pipework in remote locations. Resistant to high gamma radiation. Temperatures up to 60°C, dependant on CCTV system used. The system can be customized for each application. Full design, build, and inspection service available.

4． Necessary technologies to be developed (Example)

Dependant on application.

5． Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | System |
| Title | Remote Replacement of Water Cooled High Voltage Conductors |
| Proposed by | National Nuclear Laboratory |

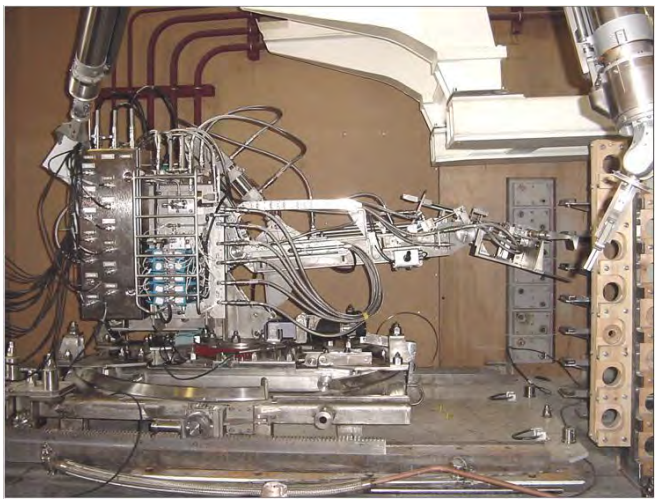
1．Description of the Technology (Features, Specifications, Performance Capability, etc.)

It was required to replace through wall conductors in a very highly radioactive and contaminated cell. These through wall conductors were the means by which high voltage electrical power was supplied to the in cell equipment. Due to mechanical damage and electrical arcing it was necessary to remove the existing in cave and through wall sections of the conductors in order to facilitate the installation of a new improved design.

The solution required the remote in-cell severing of the 14 conductors, the remote removal of the insulated conductors from the in-cell support rack and their placement in a standard sized waste drum positioned behind the in cell manipulator. The solution also involved the complete semi-remote removal of the through wall components of the conductors which included the drilling out of the existing copper pipes and enlargement of the remaining penetrations to accommodate the new conductors. On completion of the above works it was required that all the equipment was removed from the cell.

In order to achieve the above an in-cell manipulator and tooling was developed along with an out-cell drilling machine, remote viewing systems and associated control systems.

| **In cell equipment Inventory** | **Out cell equipment Inventory** |
|---|---|
| • Manipulator arm and trolley mechanism<br>• Demineralised water hydraulic system<br>• Pipe shear tool<br>• Clamp assembly<br>• Pipe reciprocating saw ( 2 types)<br>• Tie bar removal tool<br>• Power chisel<br>• Debris tray<br>• Control console<br>• TV console and in cell cameras | • Drilling machine<br>• Pull/push mechanism<br>• Raise/lower platform<br>• Hydraulic system<br>• Vacuum system<br>• Containment/bagging system<br>• Waste containers<br>• Control console and TV console |



In-Cell Manipulator

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Applied at Sellafield Nuclear Reprocessing Plant UK.

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

System Features

- Designed for use in Highly Active Areas.
- Remote replacement of conductors.
- Full suite of cutting and drilling tooling.

４．Necessary technologies to be developed (Example)

５．Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | System |
| Title | Remote Active Raffinate Pipework Diversion Manipulator System (RAFFMAN)<br>Pipe Clearance Manipulator (PIPEMAN) |
| Proposed by | National Nuclear Laboratory |

１． Description of the Technology (Features, Specifications, Performance Capability, etc.)

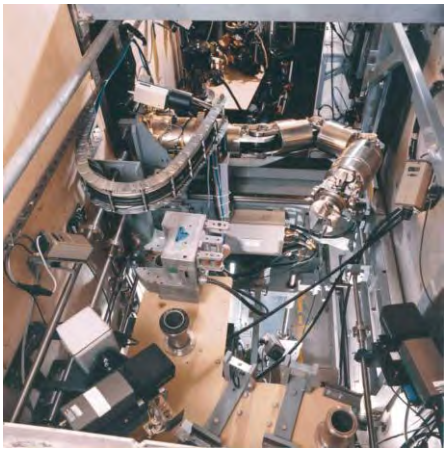
RAFFMAN

An aqueous raffinate pipeline had to be remotely diverted from one dissolver cell to another dissolver cell. This involved the cutting out of a short section of the old raffinate pipeline in the active cell and welding in a new section of pipe to the existing line.

The back ground radiation levels with in the cell prevented manual methods and so the complete operation had to be carried out remotely. RAFMAN was developed along side a series of separate work heads to cut out the section of pipe, perform weld prep machining operations, locate and clamp the substitute pipe work, clean the prepped pipe, weld the new section of pipe into place and finally perform post weld radiography to qualify the weld in a highly active cell.

The remotely operable system made provision for:-

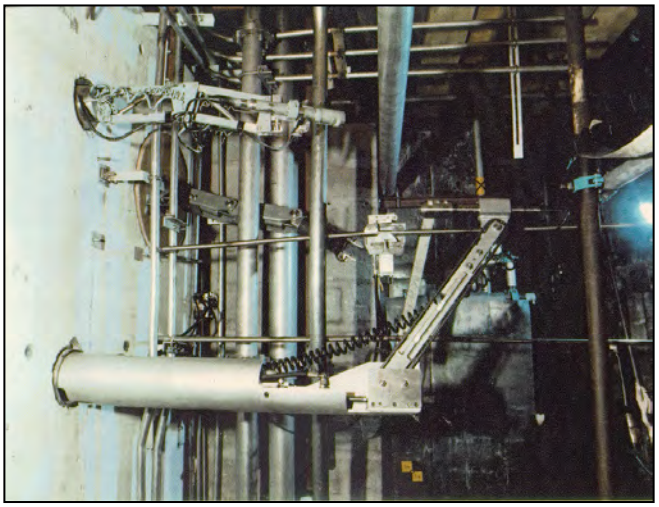
- Access for equipment through heavily shielded cell wall.
- In cell cameras and lighting.
- Full operator control system teleoperated from a remotely located control cabin.
- Cutting out and removal of a section of existing pipe work.
- Positioning and control of free end of cut pipe.
- Pipe end weld preparation & cleaning.
- Installation of the new section of pipe (Ø3 inch NB stainless steel schedule 40 pipe).
- Completing circumferential welds connections.
- A means of qualifying the integrity of the new connection by X-raying.



RAFMAN Control Desk and Manipulator

PIPEMAN

A photogrammetry exercise demonstrated that access to the raffinate line was obstructed by as-built pipe work. This meant that a number of pipes would need to be moved to gain access and complete the main diversion. A pipe clearance manipulator PIPEMAN was developed for this purpose. PIPEMAN was developed along side a range of work heads to relocate the obstructing pipe work. The range of work heads comprised a grinding head, double and single croppers, a pipe pusher and puller, a pipe spreader and a pipe bender. The grinding head was electrically powered, with all other tooling heads being hydraulically powered using demineralised water.



PIPEMAN

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Applied at Sellafield Nuclear Reprocessing Plant UK.

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

RAFFMAN & PIPEMAN Features

- Designed for use in Highly Active Areas.
- Full suite of pipe removal and pipe diversion tooling.
- Pipe bending, machining, cutting, cleaning, welding operations and weld radiography developed for remote implementation.

４．Necessary technologies to be developed (Example)

５．Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | System |
| Title | Remote Fuel Rod Retrieval Manipulator (RODMAN) |
| Proposed by | National Nuclear Laboratory |

1． Description of the Technology (Features, Specifications, Performance Capability, etc.)

RODMAN is a 'remote fuel rod retrieval system'. It was developed to retrieve Uranium fuel rods that can sometimes become displaced within an active cell. This manipulator system also assists with various maintenance and decontamination tasks within the local containment area. RODMAN has simplified and shortened intervention shut downs, and helps to reduce radiation dose uptake to operators. RODMAN self-contained, radiation shielded transport module to allow transfer between buildings.

RODMAN is a telescopic, mast mounted, six degrees of freedom, seven function, hydraulically powered manipulator. The operating fluid used is distilled water at 56 bar pressure. RODMAN is deployed from a shielded transport module that is used to move the complete manipulator system with its support services between buildings. Positional feedback is provided to the operator. A collision warning system is included. A teach and repeat facility is provided to allow complicated manoeuvring routines to be remembered and repeated. Visual feedback is provided by two onboard cameras, one mounted on the telescopic mast and the other on the manipulator forearm.

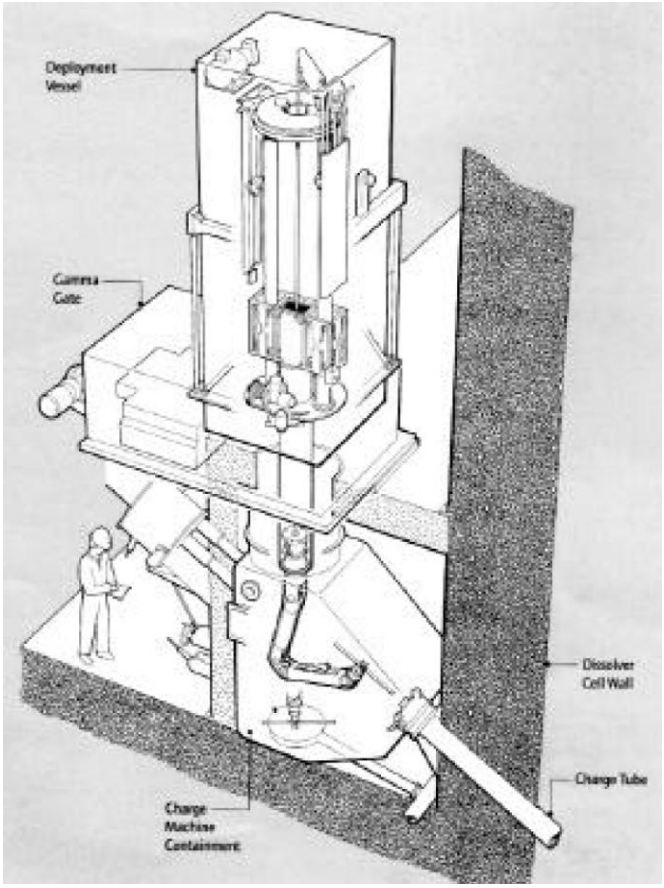



Figure 1 RODMAN in Dissolver Cell

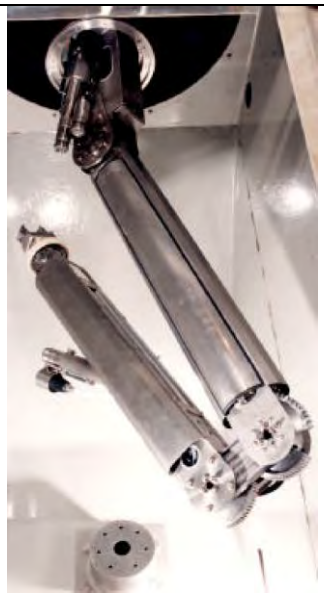


Figure 2 RODMAN

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Applied at Sellafield Nuclear Reprocessing Plant UK.

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

RODMAN Features

- Pure water hydraulic 7degrees of freedom remote manipulator.
- Electrically powered telescopic deployment mast.
- Teach and repeat and collision avoidance.
- Integral manipulator decontamination sprays.
- 70 bar pressure water spray system.
- Low pressure nitric acid spray system.
- Radiation tolerant to 10kGy (1Mrad).
- Radiation tolerant cameras.
- Remotely replaceable jaws.
- Gaitored arm system to minimise spread of contamination.
- Recoverable in failure mode.

４．Necessary technologies to be developed (Example)

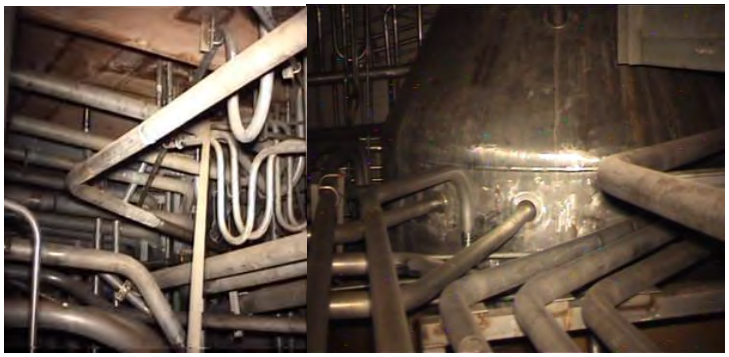
５．Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Measurement Device |
| Title | Increased CCTV coverage of close cells |
| Proposed by | National Nuclear Laboratory, UK |

1．Technical details (features, specifications and performance)

CCTV systems that can be deployed horizontally into closed cells and then deployed downwards using the horizontal to vertical adaptor to significantly increase the closed cell inspection coverage. Access can be as small as 150mm.



Plant images

Adapter

Radiation measurements of ~10 Gy/hr. Higher if tube technology is used.

2．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

These inspection tools have been used on many applications throughout Sellafield nuclear reprocessing plant (UK).

3．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

Can increase the CCTV views of closed cells. Can use other tool packages depending on the application. The system can be customized for each application. Full design, build, and inspection service available.

4．Necessary technologies to be developed (Example)

Minimal, dependant on application.

5．Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Technologies related to Manipulators |
| Title | Telepresence Robotic Inspection and Decommissioning Augmentation, Five Appendage Apparatus |
| Proposed by | MRISAR, Institute of Science, Art & Robotics. |

1．Description of the Technology (Features, Specifications, Performance Capability, etc.)

The “Telepresence Robotic Five Appendage Apparatus” has five appendages. The first appendage is a dexterous arm that is positioned at the top of the “Apparatus”. The remaining four other appendages are placed below and double as both dexterous arm manipulators for moving, placing and clamping ferrous metal materials and parts; and as legs.

Each one of the four arm/legs has three different types of “Feet”: a wheel; an electromagnetic three toed foot; and a basic hoof type foot. This combination will allow the “Apparatus” to remain in motion and upright in a variety of environmental conditions,

The “Apparatus” would use the wheels to move itself for lower current operation on fairly flat surfaces; the hoof type foot for demanding convoluted terrain; and the electromagnetic foot for walking across ferrous metal structural and containment elements.

The electromagnetic feet also double as hands to work as dexterous manipulators for moving, placing and clamping ferrous metal materials and parts.

Each combined manipulator arm/leg would have a camera mounted to it.

The primary (or top mounted) arm would also have a very dexterous hand of human configuration.

The entire device would be able to act as a mobile work fixture and workstation. Certain aspects would work autonomously. The prime dexterous parts of the device would operate in real-time by a human operator at a remote location.

The device would also be able to morph it"s self into a flatter state for narrow areas of only a few inches in width and then return to a normal configuration when more space is available.

The device would also have a series of placeable electromagnetic fixtures to mount accessories and supply containers for materials and special work applications, like drill assemblies. Part of this would also operate as a placeable system of tethers that could route materials to and from the device negating the need for it to move from its work location until the work is complete. When the work is complete it would walk to the new location and set up the new tethers.

In general terms the device would look a bit like a combination of a robotics sloth with a long neck, combined with a spider. While taking advantage of nature"s engineering examples, the device would exhibit lifelike dexterity potentials.

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

We have designed & fabricated the world's most durable and largest selection of public use robotics! We specialize in Cybernetics, Bionics, Mechatronics, Autonomics, Animatronics & Teleoperated devices. Our customers include world class science centers, museums, universities, NASA, the film industries for inclusion in media productions, royalty, foreign and domestic governments,

Our research and development in rehabilitation robotics has been presented before and/or published and awarded by: the United Nations, NASA-Emhart, Stanford, Cambridge, ICORR, ROMAN, IEEE, Discover Awards, International Federation of Robotics (IFR), etc. We were the only company in the world to be awarded an entire chapter regarding our robotic work in the International Federation of Robotics (IFR) “World Robotics; Service Robotics, 2011”.

Our 1990's circa, original innovative research & development in "Facial Feature Controlled Technology" and "Artificial Sense of Touch Technology", (Adaptive Technology prototypes for the disabled), has helped pioneer those fields!.

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges.

We have been conducting research and development with “Telepresence Mobile Robotics for Emergency Use” for many years.
Our research categories are: Surveillance & Security Robots in Commercial Applications; Robots to assist human guards, or too keep vigil in extremely hazardous areas; Bomb Retrieving Robots- Robots that can retrieve and isolate or disarm bombs; Fire Fighting Robots- Robots that can fight fires and go into high temperature and toxic environments that humans cannot enter: Surveillance & Security Robots in Domestic Applications- Robots that monitor security and safety in home environments.

４．Necessary technologies to be developed (Example)
This “Apparatus” is based on technologies we have already developed.

５．Notes
The above proposal is within our area of expertise. We are can take this concept from

design to working prototype within a short span of time.

Please place a check mark to identify that this technology is either in:

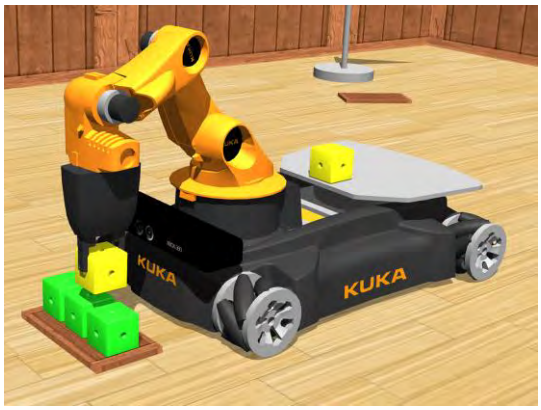
x a research and development phase or ☐ a practical application phase.

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Software |
| Title | Simulator Technologies for Operator Training |
| Proposed by | Cyberbotics Ltd. / Dr. Olivier Michel |

１． Description of the Technology (Features, Specifications, Performance Capability, etc.)

*Cyberbotics develops the award winning Webots robot simulator. This robot simulation software is the leading commercial robot simulation software in the world. It is being used by over 1,000 universities and research centers worldwide. Webots has been developed for more than 15 years as a spin-off of the Swiss Federal Institute of Technology in Lausanne (EPFL). It is currently used in a European Research projects for simulation and remote-control of agricultural robots (RHEA). It has been used to simulate different kinds of mobile manipulator, including KUKA youBot (see picture below).*



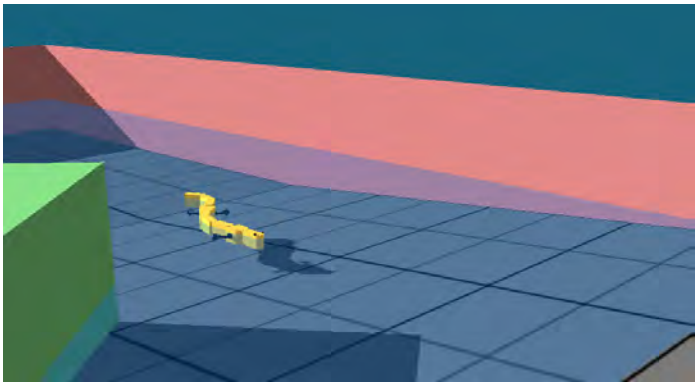

*Webots provide an exhaustive library of robotics sensors and actuators: cameras, range-finders, US & infra-red distance sensors, touch, position and force sensors, GPS, IMU, accelerometers, gyros, compass, motors, grippers, LEDs, communication devices, etc. Libraries of common objects are provided to easily create 3D simulated environments for robotics simulations (including indoor and outdoor scenarios).*

*All sensors and actuators are properly calibrated against real devices, so that the behavior obtained in simulation is similar to the behavior of real devices.*

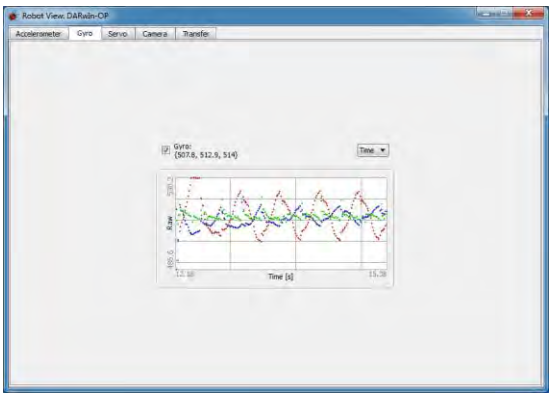
*Webots also include a realistic physics engine allowing the user to simulate the dynamics of the robot and environment. As the results, the simulations developed with Webots are realistic and transferable to real robots.*

*The physics engine used in Webots is a multi-threaded version of ODE (Open Dynamics Engine) which combines realism, stability and efficiency to provide real time 3D simulation models.*

*Physics plug-ins allow to simulate fluid dynamics to model flying and swimming robots as depicted below with a salamander robot:*



*In addition, Webots provides facility libraries to develop user interfaces to interact with a human operator. This is particularly useful to visualize the state of the different devices of a robot (camera, motors, etc.) and to drive the robot:*



*For more information about Webots, please visit* http://www.cyberbotics.com

2． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

*Cyberbotics has a long history of collaboration with Japanese companies and universities involved in robotics research. These companies include Sony corp. (for which Cyberbotics developed an Aibo robot simulator), Hokuyo (for which Cyberbotics developed models of their range-finder products), Fujitsu (for which Cyberbotics developed a model of the HOAP-2 robot) as well as many companies and universities as listed in appendix A. Cyberbotics has also been working on development projects with several other abroad companies, including the Stanford Research Institute (USA), Aldebaran Robotics (France), Robotis (South Korea), The University of Nevada in Reno (USA), etc. as well as several in European Research projects involving 10-15 partners from both industry and academy, including BAE systems (UK) or Case New Holland (Belgium).*

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

*The Cyberbotics technologies is certainly applicable to develop an accurate VR (Virtual Reality) and Mixed Reality simulation of the robotics systems and TEPCO Fukushima Daiichi Power Plant. It includes the necessary components (robotics sensors and actuators, including realistic camera models, physics simulation, mobile manipulator systems, possibility to simulated fluid dynamics, graphical user interfaces, etc.).*
*Modeling of the robots and environments can be achieved from 3D CAD data, as Webots can import 3D CAD data easily. Such CAD data can be obtained from razor scanning and/or CAD drawings. In addition to this data, it will be necessary to input other values such as the mass distribution for the robot and moveable objects (doors, pipes, chairs, etc.).*

４．Necessary technologies to be developed (Example)

*It shouldn't be necessary to develop any special or complex technologies as Webots already includes all what is needed to develop such a simulation. The development will be mainly focused on the 3D models (robots and environment) which are specific to the TEPCO's Fukushima Daiichi Nuclear Power Plant and for example the Quince Robot developed by Chiba Institute of Technology. They will also include the design and implementation of graphical user interfaces aimed the training of the human operators. This graphical user interface will be connected to the simulation models, and possibly to remote-controlled robots (mixed reality).*

５．Notes

Please place a check mark to identify that this technology is either in:
☐ a research and development phase or ☑ a practical application phase.

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Transportation Equipment/ Working Equipment/ Measurement Device/ Support Device/ System |
| Title | Experts in stakeholder engagement, communication, governance, risk and sustainability – strategy development, planning; implementation and engagement delivery; evaluation and assurance |
| Proposed by | |

１． Description of the Technology (Features, Specifications, Performance Capability, etc.)

Article 13 are a strategic consultancy, established 15 years ago. Based in the UK, we operate globally with regional partners in Asia, Africa, Middle East and North America. We bring together global experts from our formal associate network.

We have particular experience operating within the nuclear sector (from new build through to decommissioning). Our work typically involves working alongside organisations (often acting as a critical friend) around their communication and engagement strategy and plans – international, national, regional and local stakeholders.

We support organizations address the key issues facing their organization and their stakeholders.

A particular area of expertise in the nuclear sector is around Stakeholder communication and engagement

- Stakeholder and issue mapping
- Consultation engagement analysis (including engaging hard to reach groups)
- Building communication strategies based on material issues
- Activation and relationship building
- Liaising with multiple stakeholders (national, regional and local) including government bodies
- Developing, managing, delivering and evaluating stakeholder engagement programmes in a complex communications environment.
- Spokesperson training
- Media relations team

- Crisis communications

Other services include

- **External review and appraisal of existing programmes** – *what is working, what is not, how can existing programmes deliver greater value to the business and society.*
- **Impact assessments** – *Including environment, social and health impact assessments (based on current baseline and with future projections)*
- **Strategy development** – short and long-term planning
- **Training / capacity building** - *including E-learning*
- **Stakeholder engagement and communications** – *engaging stakeholders through traditional and online media*
- **Behaviour change and social marketing -** *including social return on investment and impact analysis*

２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Our experience and clients, include;

- **World Nuclear Association:** Messaging work for the Uranium Working Group of the WNA on producing a stakeholder relevant and understandable mission and vision
- **International Atomic Energy Agency:** engaged as an advisor for the development of Guidance on Stakeholder Involvement in Decommissioning
- **British Nuclear Fuels Limited:** Worked with senior management to understand key stakeholder perspectives of the areas of future risk for the nuclear industry
- **Nuclear Decommissioning Authority / Radioactive Waste Management Directorate:** Framework suppliers for stakeholder engagement and communication
- **Nuclear Decommissioning Authority:** Acted as the lead facilitator and process adviser for the National Stakeholder Group

３． Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

| |
|---|
| 4．Necessary technologies to be developed (Example) |
| 5．Notes<br>article 13<br>THE RESPONSIBLE BUSINESS EXPERTS |

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Contamination/Waste Treatment, Capture and Sequestration |
| Title | CyCurex® Technology for Scrubbing and Sequestration of Air and Liquid-borne Heavy Metal Radio Nucleotides. |
| Proposed by | Cylenchar Limited |

１． Description of the Technology (Features, Specifications, Performance Capability, etc.)

CyCurex® of Cylenchar Limited UK is a patented generic reagent for the remediation of toxic heavy metals contaminated materials, including radio nucleotides of Periodic table Group II and above. CyCurex® can bind and stabilize a broad spectrum of heavy metals in a wide variety of substrates, and eliminate or reduce metals leaching to within internationally accepted regulatory limits, thereby preventing contamination of soil and/or ground water. Treated soils can be rendered compliant with US-EPA-Universal Treatment Standard (UTS) Limits and EU Waste Acceptance Criteria (WAC) limits set out in WAC Directive 2003/33/EC and derived from Directive EU 1999/31/EU. Treated materials will pass testing by US-TCLP, DIN38,414S(4), UK-NRA, UNI 10802.A.2 and EN12457 methodologies. Successfully treated substrates will withstand Multiple Extraction Procedure (MEP) long-term stability tests, indicating >1,000 year treatment stability to acid rain and oxidative degradation.

Potential applications: In-situ and ex-situ contaminated land remediation. Heavy metals sequestration of combustion gases from coal fired power plants, cement kilns and waste incinerators. Contaminated water treatment. Chemical waste treatment. Oil field off-gas sequestration. Abatement of airborne or liquid-borne radio-nucleotide contamination...

http://www.cylenchar.com

２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

The CyCurex® process has been tested and proven at the Southern Research Institute 1MW themal testing facility, Birmingham Alabama, USA. The system is presently being scaled up for installation in multi-mega watt scale coal fired power facilities in the US Power Utility sector.

As an illustration of CyCurex"s capability, SRI test results demonstrated that in a coal combustion gas stream carrying a concentration of 1,000μg/M³ total mercury and at least 34μg/M³ of elemental mercury, CyCurex® was easily able to reduce the total mercury concentration by >90%, and it was able to deal with >75% of the elemental mercury in timescales of 1.1 to 2.2 seconds. Wastes were concentrated and contained in a non leaching form within a stabilized

gypsum matrix, with thermal stability >360°C. This residue is suitable for inclusion within a cement matrix. Stability of treatment residues to leaching is illustrated below:-

| CyCurex® - PRB-Bituminous blended coal combustion gas Vessel Residue Heavy Metals Analysis | | | |
|---|---|---|---|
| **Heavy Metal** | **Total Metals Content mg/Kg** | **Leachable Metals By UK-NRA, TCLP equivalent procedure mg/Litre** | **TCLP Regulated Limit 40CFR Part 261.24 mg/Litre** |
| Arsenic | 4.2 | 0.00084 | 5.0 |
| Antimony | 0.72 | 0.00055 | 1.0 |
| Cadmium | <0.20 | <0.00020 | 1.0 |
| Chromium | 690 | 0.0017 | 5.0 |
| Copper | 47 | 0.020 | N/A |
| Lead | 5.0 | 0.0052 | 5.0 |
| Mercury | 67 | 0.0012 | 0.2 |
| Nickel | 350 | 0.26 | 10.0 |
| Selenium | 29 | 0.11 | 1.0 |
| Zinc | 25 | <0.0060 | 700 |

3．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

Known chemistry of CyCurex® in sequestering broad spectrum of heavy metals (encompassing radio nucleotides), and parallel work undertaken with Cylenchar"s CyFix® at BNFL, Sellafield, Cumbria, UK on treating high level liquid nuclear waste, wherein it removed 70% of the activity from the waste stream, enabling 3 times recycling of treatment fluids prior to disposal rather than single use.

4．Necessary technologies to be developed (Example)

Not applicable

5．Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Computer Systems – Nuclear Land and Building Pollution Management & Remediation |
| Title | Computer System for Nuclear Land and Building Pollution Management and Remediation |
| Proposed by | **Informed Solutions** |

1． Description of the Technology (Features, Specifications, Performance Capability, etc.)

InformedLANDQUALITY is a software system based on open communications and interface standards for collecting data on nuclear pollutants from land and inside buildings.

InformedLANDQUALITY has been designed to work in environments where high levels of nuclear pollutants mean that contamination sampling must be done using robots or other remote controlled vehicles, as well as from laboratory sampling. The system can receive data directly from mobile robotically positioned sensors, or from static remotely deployed sensors including sensors located above and below ground, and located underwater. InformedLANDQUALITY uses a variety of open standards, including XML and IP, to communicate with remote sensors via radio or fixed wire links.

InformedLANDQUALITY is fully BIP0008 compliant, and can be linked to a Geographic Information System (GIS) or Computer Aided Design (CAD) package to display a 2 or 3 dimensional view of contamination inside buildings or affected land. It can be installed locally, or accessed on a secure cloud based service.

Other capabilities include:

- Managing building and land sampling programmes
- Managing and analysing data received from robots, remote sensors and laboratory analyses
- Interfaces with other industry standard systems including Rockworks, IMAGES, eFacility, MS Excel, MS Access, MS SQL Server, Oracle, ESRI ArcGIS and Laboratory Systems
- A single hub for managing data and information, with a simple to use Web based interface, flexible reporting and tools to import and export data to other applications
- Support for remediation and land quality management programmes, including trend analysis and scenario modeling

**Benefits achieved by existing clients using InformedLANDQUALITY include:**

- Greater integrity, reliability and quality for building and land contamination information.
- Reduction in the number of building and land management systems handling different aspects of remediation, management controls and quality assurance, with corresponding reductions of up to 50% in ongoing information management costs.
- Significant costs reduction through better monitoring and understanding of risks and liabilities and effectiveness of remediation activities.
- Improved auditability, legislative compliance and reputation management.
- Simplification and streamlining of reporting processes, providing greater assurance of business and safety critical functions, as well as regulatory reporting.
- Enhanced decision support for the design and execution of £multi-billion remediation programmes, especially the targeting and improvement of remediation measures.

２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Informed Solutions was founded in 1992, and is an independent professional services and systems integration practice.

We have more than 20 years‟ experience in the energy industry, working with global oil and gas majors, national electricity generators and distributors, and nuclear waste and reprocessing sites.

We provide a range of specialist services and systems to the energy industry including building and land quality management, asset management, regulatory licencing, workflow automation and case management. Informed Solutions has some 20 consultants in our energy practice and a broad network of specialist alliance partners and associate subject matter experts.

Example projects that Informed Solutions has delivered include:

**Sellafield Ltd (Europe’s largest nuclear reprocessing site)**

We have provided a Land Quality System to manage a 60 year legacy of land contamination from nuclear activity that is being used to clean-up buildings and land at the Sellafield nuclear site. The system manages over 700 types of groundwater and soil contamination

data over a 40 year period, and seamlessly integrates information from 8 different systems.

**Shell Retail International (International Fuel Retail division of Shell)**
We have provided Land Quality Systems to manage hydrocarbon contamination of buildings and land and associated clean-up activities at Shell's fuel retailing sites in some 40 countries worldwide.

3．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

The InformedLANDQUALITY platform has been specifically designed for capturing nuclear pollutant data using laboratory samples and from sensors at contaminated nuclear sites. These are sites where:

- There is a need to capture, store and analyse large volumes of data from sensors
- High contamination levels require the use of robotic or remote controlled vehicle mounted sensors
- Contamination has occurred inside buildings and/or affected land
- There is a need to visualise levels of contamination, to assist with assessment and planning of remediation strategies

The InformedLANDQUALITY platform incorporates open-standards interfaces to allow communication with industry standard sensor equipment and the use of radio and fixed wire communications links, making it highly suitable for multi-vendor environments.

4．Necessary technologies to be developed (Example)

Use of InformedLANDQUALITY does not require any further technologies to be developed.

5．Notes

A presentation showing the capability of InformedLANDQUALITY, and further information is available from Justin.Hassall@Informed.com or David.Chapman@Informed.com.
Please find attached to this submission both our company logo and data integration and advanced analytics solution logo (which underpins the InformedLANDQUALITY platform), for publication in the Technical Catalogue along with this entry.

［Format 2］

| Technical Catalog | |
|---|---|
| Category | DECOMMISSIONING SUPPORT |
| Title | GENERAL SUPPORT |
| Proposed by | NDSL |

NDSL is a specialist nuclear decommissioning company working across the UK and Europe. Key capabilities are:

- Decommissioning Design, Planning and Implementation
- Nuclear Ventilation Design and Installation for Decommissioning
- Alkali Metal Disposal

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

NDSL has worked at UK nuclear plants; Dounreay, Sellafield, Trawsfyndd, Bradwell, Berkley and Winfrith and in Europe; EU Joint Research Centre in Italy and WAK GMbH in Germany.

３．NDSL has extensive decommissioning experience and it is one of a small number of UK companies who have a track record of disposing of bulk Alkali Metal.

４．None

５．Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Working Equipment/Measurement Device/ Support Device/ System |
| Title | 3D Laser Scan and Structural Stability Appraisal |
| Proposed by | NW Structural Consultants Ltd |

１． Description of the Technology (Features, Specifications, Performance Capability, etc.)

Laser scanning technology has been used by a partner consultant of ours to collate detailed high-accuracy spatial data of existing plant and equipment in high radiation areas at Sellafield, Cumbria, UK. This information can then be used to generate 3d video fly-over visualization graphics, 3D CAD models, and highly accurate (e.g. + or – 5mm) traditional 2D engineering drawings. A vast amount of spatial data is collected in a relatively short period of time. The information is processed by skilled personnel using specialist software at remote locations to enable details of necessary structural modifications (e.g. to pipe support structures) to be developed. Even the relative size and position of bolts in structural steelwork connections can be determined.

The applications need not just be limited to structural work, for example, the amount of sag in electrical cables can be detected, and good use of the technology has been made in the UK rail industry where tracks have been surveyed without the need to stop services.

２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

NW Structural Consultants Ltd use Chartered Structural Engineers to assess existing structures for adequacy in extreme unconventional circumstances. Our experience is largely in the UK nuclear power industry, but has also extended to the offshore wind, oil and gas industry where we have been responsible for the temporary works design, structural stability and lifting/moving logistics of structures exceeding 200T.

We recently successfully completed a research project for a large Japanese consultant who operate in the water, sewerage and environmental sector.

３． Basis for determining the technology is applicable to Fukushima Power Plant and

| |
|---|
| technical challenges<br><br>A lot of accurate spatial data related to damaged structures, plant and equipment can be obtained very quickly to provide good visualization by personnel remote from the site. The information is also very accurate and can therefore be used to develop engineering strategies and designs. |
| ４．Necessary technologies to be developed (Example)<br>- Development of laser scanning technology in an under-water environment<br>- Development of software to interpret data obtained from a mobile survey point (e.g. attached to an aerial flight device or under-water submarine/vessel) |
| ５．Notes<br>- A separate partner organization has developed an electronic glove that can be used to remotely control a robotic hand with the aid of a visual monitor. Not only could this have applications with the above proposal, it could also be developed for other more specific remote applications. |

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Radiation 3-D Imaging system with combined laser scanning and spherical imaging. |
| Title | **N-Visage™ 3-D System** |
| Proposed by | REACT Engineering |

1． Description of the Technology (Features, Specifications, Performance Capability, etc.)

**N-Visage™ Scanner**

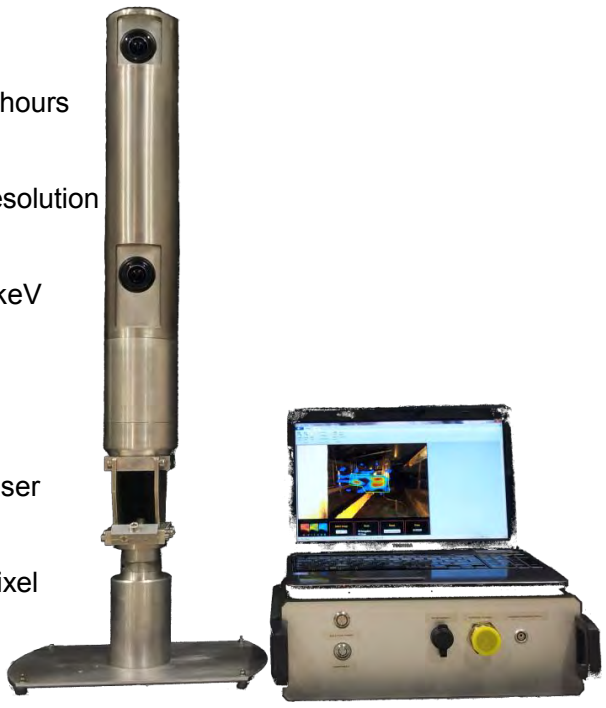
**Remote nuclear characterisation system**

The N-Visage™ Scanner is the world's most capable and versatile radiation scanning system for the nuclear industry. Designed to by nuclear engineers for nuclear engineers, N-Visage™ is the first characterisation system aimed specifically at challenging deployments through small apertures and in high dose areas (up to 1 Sv/hr).

The capabilities of N-Visage™ are enabled by its unique imaging system based on CZT detector technology. This enables a light system deployable through small apertures with extremely high background rejection, high spatial resolution, high energy resolution up, and 360 degree viewing.

**Features:**

- Full 360° by 360° gamma image
- Completes gamma images in under 2 hours
- Software controllable scan time and resolution
- Energy resolution: 3% FWHM @ 662 keV
- Energy range: 30 keV to 2 MeV
- Integrated spherical camera and 3D laser
- Spherical image resolution: 12 Megapixel
- Point cloud range 10m, res. +/- 30mm



- High dose tolerant: up to 1 Sv/hr
- Fits through small apertures: 110mm OD
- Low mass: 10 – 15 kg (configurable)
- Umbilical length of up to 125m


２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Extensive experience in United Kingdom at Sellafield Ltd.

３． Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

System will give clear definition, clarity and certainty of the radiation environment in 3-D enabling “What If” intervention scenarios to be modelled and structured clean up and decommissioning strategies to be prepared based on fact.

System is applicable for all complex radiation environments. – Maximum dose levels yet to be determined.

**Please see “Example Projects” at end of this document.**

４． Necessary technologies to be developed (Example)

Associated remote deployment methods and technologies.

５．Notes

The system and technology is currently being appraised by TEPCO & HGNE

The N-Visage™ Scanner is also equipped with a spherical camera and laser rangefinder: each scan produces detailed radiometric, geometric and optical data. This makes the N-Visage™ Scanner a single package solution to most characterisation challenges.

**Applications:**

- Characterise reprocessing and fuel handling facilities using existing service ports.
- Post-event characterisation and response.
- ROV deployed characterisation tasks.
- Understand and control the sources of dose in high-dose manual tasks.
- Remote waste assessments.

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Transportation Equipment/ Working Equipment/ Measurement Device/ Support Device/ System |
| Title | |
| Proposed by | Tata Steel Projects（書式未記入） |
| １．Description of the Technology (Features, Specifications, Performance Capability, etc.) | |
| ２．Past experience (plants in Japan, overseas plant, applications in other industries, etc) | |
| ３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges | |
| ４．Necessary technologies to be developed (Example) | |
| ５．Notes<br><br>Please place a check mark to identify that this technology is either in:<br>☐ a research and development phase or ☐ a practical application phase. | |

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Transportation Equipment/ Working Equipment/ Measurement Device/ Support Device/ System |
| Title | |
| Proposed by | Tata Steel Projects and Siempelkamp Nuclear Technology UK<br>（書式未記入） |
| １．Description of the Technology (Features, Specifications, Performance Capability, etc.) | |
| ２．Past experience (plants in Japan, overseas plant, applications in other industries, etc) | |
| ３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges | |
| ４．Necessary technologies to be developed (Example) | |
| ５．Notes<br><br>Please place a check mark to identify that this technology is either in:<br>☐ a research and development phase or ☐ a practical application phase. | |

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Measurement Device |
| Title | Cosmic-ray Muon Radiography |
| Proposed by | UK National Nuclear Laboratory (UK NNL) |

1． Description of the Technology (Features, Specifications, Performance Capability, etc.)

Cosmic-ray muon radiography has the potential to allow the internal distribution of high-Z components/materials to be imaged from outside the physical containment volume. The technique utilises a passive technique (cosmic background radiation) to provide an image of the volume under consideration and differentiates between high-Z (e.g. uranium in fuel rods) and lower-Z material (steel/iron).

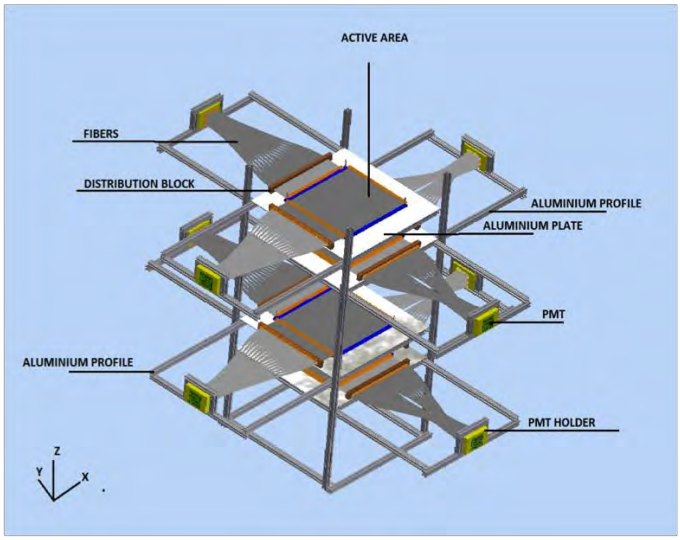



**Figure 3: UK NNL – Small-scale prototype muon imaging system**

2． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

The UK NNL has been developing muon radiography for Sellafield Ltd. (on behalf of the UK Nuclear Decommissioning Authority) for more than 3 years with the overall aim of imaging the internal contents of ILW (Intermediate Level Waste) containers. A small-scale prototype detector system (Figure 1) has been commissioned and has demonstrated clearly the ability to distinguish between (relatively) small quantities of uranium and steel with good resolution.

3． Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

It is a remote technique to assess the internal distribution of materials (e.g. U) within a given containment volume – applicable to Fukushima.

4． Necessary technologies to be developed (Example)

The current detector system utilises muon (coulomb) scattering to image the content volumes – for Fukushima it is likely that muon attenuation would be utilised). A scale-up of the detector system (from imaging ILW containers) would also be required) along with associated modeling (Monte Carlo simulations)

5． Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Software |
| Title | ENIGMA - Fuel behaviour modelling software |
| Proposed by | National Nuclear Laboratory (NNL) |

１．Description of the Technology (Features, Specifications, Performance Capability, etc.)

The ENIGMA code is the UK's principal tool for thermal reactor fuel design and licensing assessment. It has a long pedigree of application to various different reactor systems in the UK and Europe. The code models the evolution of the thermal and mechanical state of the fuel, together with the changes caused by the generation and redistribution of fission products. The code calculates the parameters (stresses, temperatures, strains, corrosion, etc) which need to be compared with the safety criteria for licensing of the fuel design under both steady state and off-normal conditions. The code has been validated by comparison with in-pile measurements from test reactor experiments and post-irradiation measurements on spent commercial reactor fuel; over 500 separate rod irradiations have been utilised for this. The code is in active use by NNL and other UK nuclear stakeholders, and is underpinned by a substantial ongoing development and validation programme. The code offers complete independence from similar tools developed by reactor and fuel vendors.

Particular strengths of the code include: (a) state-of-the-art capabilities for the modelling of MOX fuel (described further in [1]); (b) ability to model fuel rods after irradiation, such as in spent fuel ponds, in transport and in dry storage (described further in [2]); (c) in combination with the NEXUS system linking ENIGMA with SSP's neutronics codes CASMO-SIMULATE, the ability to efficiently model all rods in a reactor core (also described further in [2]).

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

ENIGMA calculations have been used to support the licensing of UO2 in-reactor fuel operations in the UK (AGR and PWR) and Finland (VVER), and the licensing of in-reactor MOX fuel operations in Switzerland (PWR). It has also been used in support of design and planning of out-of-pile fuel operations in the UK including transport and long term storage.

| |
|---|
| 3．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges<br><br>Potential areas of application for a fuel behaviour code such as ENIGMA include: (i) assessment of fuel failure probability as a function of operational parameters; (ii) assessment of radioactive fission product inventory and instant release fraction of spent fuel; (iii) scenario modelling for spent fuel treatment options such as transport and storage. |
| 4．Necessary technologies to be developed (Example) |
| 5．Notes |

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Effluent Treatment |
| Title | Process Intensified Chemical Precipitation |
| Proposed by | Dr Luke O"Brien |

1． Description of the Technology (Features, Specifications, Performance Capability, etc.)

Compact chemical precipitation plant.

Chemical precipitation is used to remove a wide range of radionuclides dissolved in aqueous solution (e.g. caesium, strontium or plutonium) usually by addition of an alkali to increase pH so that radionuclides are co-precipitated as insoluble carbonates or hydroxides. Where possible it is desirable to exploit the stream chemistry to avoid addition of reagent and hence reduce secondary waste arisings.

National Nuclear Laboratory (NNL) have developed an intensified flocculation process based on the use of High Intensity Vortex Mixers, dedicated floc growth vessels and tight on-line pH control. Because the mixing is „fast" there are no concentration gradients resulting in a tight size distribution. The floc produced is crystalline rather than spongy. These properties enhance dewatering of the product. The mixers are fluidic i.e. free from moving parts. Compact footprint.

Example Dimensions

The footprint for a feed throughput of 0.5m3 /hr is 1.5 x 2.5m2.

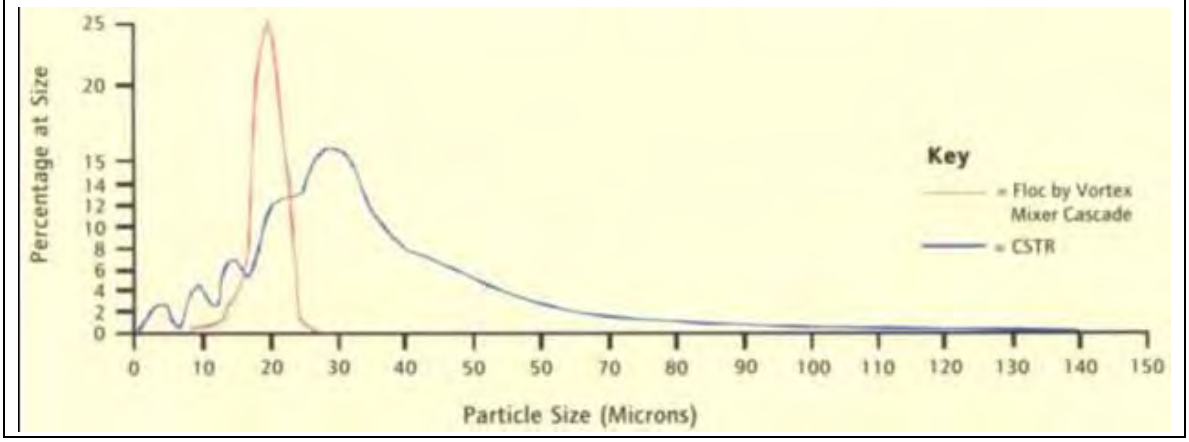
The height is 2m and the plan area is 6m2.

The size of the vessels used will vary depending on feed throughput.

Comparison of precipitation plant parameters

| | Conventional | Modular (Intensified) |
|---|---|---|
| Process volume V ($m^3$) | 500 | 0.2 |
| Throughput v ($m^3$/hr) | 10 | 0.5 |
| Residence Time V/v (hr) | 50 | 0.4 |

Comparison of precipitated floc particle size distribution of conventional continuous stirred tank reactor (CSTR) with intensified mixing.



| |
|---|
| ２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)<br>The chemical precipitation process has been employed for over 20 years for the treatment of radioactive effluent at the Enhanced Actinide Removal Plant. A process intensified arrangement (depicted above) was developed for deployment in non-nuclear trade effluent treatment. |
| ３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges<br>Process intensified plant can provide increased throughput with reduced footprint through improvement in floc settling and dewatering characteristics. |
| ４．Necessary technologies to be developed (Example)<br>Design modification would be required to account for application specific shielding requirements. |
| ５．Notes |

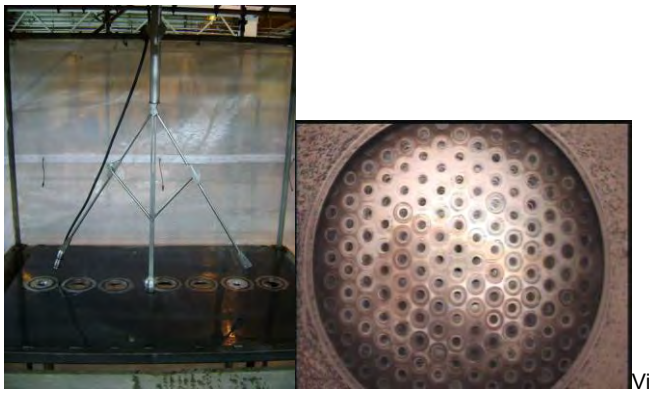
［Format 2］

| Technical Catalog | |
|---|---|
| Category | Measurement Device (including deployments system) |
| Title | Tube boiler thickness surveys using radial deployment system. |
| Proposed by | National Nuclear Laboratory, UK |

## １． Description of the Technology (Features, Specifications, Performance Capability)

Radial deployment system developed to provide process side ultrasonic thickness/CCTV/ tube cleaning and radiation level survey of the full length of 5m long austenitic stainless steel tubes located in a vessel within a closed cell. Access via a 150mm internal bore, 15m long (vertical) standpipe located out side the cell. Up to x210 tubes per boiler. No motors used within the system. Designed for up to 3m tube boiler diameter with potential to increase where necessary. Vertical deployment length can be increased. Greater than 360° rotation achievable. Inspection tools developed are for CCTV to assess corrosion and deposit loading, tube wall thickness survey using ultrasonic thickness measurement system including in-built water retention for sound couple, deployment of tube washing system, and gamma radiation measurement capability.

Deployment system in full scale mock-up



View of vessel　tubeplate top.

## ２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Used successfully within Sellafield Nuclear reprocessing plants, UK, in five different vessels.

## ３． Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

Remote sensor deployment through small access locations providing greater characterization of closed cells and plant condition. Can be used in high radiation environments, gamma radiation levels of up to 5-10 Gy/h. Temperatures up to 60°C, dependant on CCTV system used. The system can be customized for each application. Full design, build, and inspection service available.

## ４． Necessary technologies to be developed (Example)

Possible increase lateral movements dependant on application.

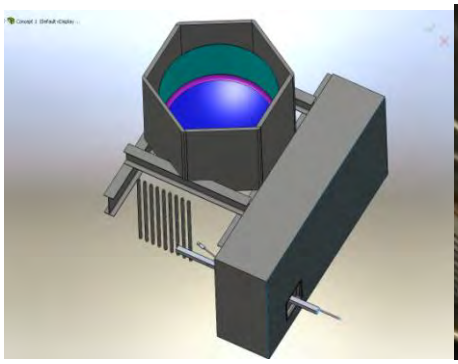
## ５． Notes

［Format 2］

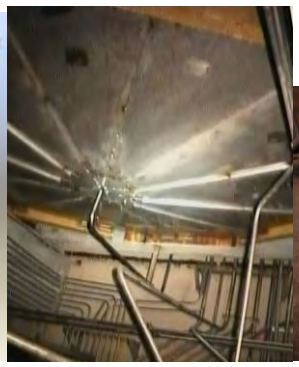
| Technical Catalog | |
|---|---|
| Category | Measurement Device (CCTV inspection in closed areas) |
| Title | CCTV inspections beyond obstructions in closed cells |
| Proposed by | National Nuclear Laboratory, UK |

## １. Technical details (features, specifications and performance)

CCTV inspection system deployed horizontal into a closed high radiation cell and then able to be deployed radially to view beyond cell obstructions. Currently 4m deployment systems available, within longer systems possible. Rack and pinion controlled deployment system for horizontal movement. CCTV system with full pan/tilt/zoom/integrated illumination.



CAD model



Plant view

Equipment

## ２. Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Has passed the Sellafield (UK) design authority requirements for deployment into cell.

## ３. Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

CCTV systems that provide greater capability for views in closed cell support the understanding of the plant condition. Can be used in high radiation environments by using tube camera technology, otherwise gamma radiation levels of up to 10 Gy/h. Temperatures up to 60°C, dependant on CCTV system used. The system can be customized for each application. Full design, build, and inspection service available.

## ４. Necessary technologies to be developed (Example)

Possible increase horizontal and lateral movements dependant on application.

## ５. Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Measurement Device |
| Title | RadLine® |
| Proposed by | National Nuclear Laboratory (NNL) |

１．Description of the Technology (Features, Specifications, Performance Capability, etc.)

RadLine® is a real time dose rate detector which comprises of a scintillation crystal coupled to a fibre optic cable. The system is very small and easily deployed due to the flexibility of the cable in hard to access or small entry areas. Each RadLine® is custom built to a required specification based on dose rates, access to the area, need for protection against impact or water etc. The size and weight of the RadLine® will vary based on these parameters. A „standard" system comprises of a 1 mm x 1mm x 30 mm crystal, on a 20m long 1 mm diameter fibre which weighs a few hundred grams.

The RadLine® is very tolerant of high radiation levels. The system has been proven to detect dose rates from 0.2 mSv/hr to **several thousand Sv/hr**. A standard system can detect from 10 mSv/hr to over 8000 Sv/hr. The fibre is resilient to a total dose of over 50,000 Gy.

The RadLine® offers real time data with the capability for prolonged recording with time stamping. The RadLine® is not collimated so provides point dose measurements. The RadLine® is sensitive to temperature and therefore not recommended to be used at a temperature which differs largely from the calibration temperature unless only relative rather than quantitative measurements are required.

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

RadLine® has done a variety of trials within the UK including underwater trials and the RadLine® has been used on Sellafield site and Dounreay site where a temperature factor was taken into account.

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

RadLine® is very applicable for use in Fukushima based on its resilience to high dose rates and deployability / size. The technical challenge will be the temperatures where the RadLine® is deployed.

| Applicable Issue | Applicability | Remarks |
|---|---|---|
| Usability in a radioactive environment | YES | Highly radiation resistant, all electrical read out system is kept out of the active area and therefore there are no electronics in the active area. The fibre and the crystal have been proven to be highly radiation tolerant. |
| Usability in a high-temperature environment (60°C) | YES | Recently the RadLine® was used in temperatures up to 95°C. |
| Usability in a high-humidity environment (60°C) | YES | RadLine® has been tested underwater for 90 hours. |
| Investigation of position/status of fuel debris inside RPV | YES | A series of RadLines® should be considered to map the area of interest inside the RPV. Modelling has shown that RadLine® has the potential to locate fractions of fuel elements in a background material. |
| Investigation inside the PCV | YES | Due to its size and applicability in high radiation areas and underwater, the RadLine® could be used to locate radiation hotspots within the PCV. |

４．Necessary technologies to be developed (Example)

Collimation device for non-point measurements.

５．Notes –

RadLine® flyer and case study attached

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Training |
| Title | Coupling Training Quality management and Validation Services |
| Proposed by | Scottish Environmental Research Centre (SUERC), University of Glasgow |

１．Description of the Technology (Features, Specifications, Performance Capability, etc.)

We can offer training in all aspects of nuclear technology, the nuclear fuel cycle and environmental management and monitoring, and associated quality management. All training can be tailored to suit professional requirements of individual organizations. In addition the School of Physics and Astronomy the University of Glasgow offer a 1-year MSc taught postgraduate degree program in Nuclear Technology. The course comprises of the following core modules:

- Environmental Radiation
- Nuclear Power Reactors
- Imaging and Detectors
- Medical Imaging
- Detection and Analysis of Ionising Radiation
- Research Skills
- Problem Solving Workshops
- Advanced Data Analysis

We have more than 30 years of research reactor, operating reactor, and training experience including regulation and quality management of a nuclear site. SUERC also has experience of:

- reactor decommissioning;
- site evaluation;
- preparation towards and implementation of site de-licensing to green field conditions.

External auditing services can also be supplied.

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

３．Basis for determining the technology is applicable to Fukushima Power Plant and

| |
|---|
| technical challenges |
| ４．Necessary technologies to be developed (Example) |
| ５．Notes<br>http://www.gla.ac.uk/postgraduate/taught/physicsnucleartechnology/ |

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Measurement / Analysis Service |
| Title | Accelerator Mass Spectrometry Analysis of Long Lived Radionuclides |
| Proposed by | University of Glasgow School of Physics and Astronomy<br>& Scottish Environmental Research Centre (SUERC) |

１．Description of the Technology (Features, Specifications, Performance Capability, etc.)

Researchers from Nuclear Physics Group in the School of Physics and Astronomy at the University of Glasgow and staff at the Scottish Environmental Research Centre have unique facilities and expertise in accelerator mass spectrometry of diverse nuclides. They have conducted measurements of $^{129}$I in air filters, water, and biomass in samples from Japan working in collaboration with institutions and universities in Japan.

SUERC also has two established $^{14}$C laboratories. It leads on several international radiocarbon inter-comparison studies and is involved in the Fifth International Radiocarbon Inter-comparison Exercise.

Both of these nuclides are increasingly relevant for the characterization and reconstruction of the deposition pathways and redistributional behavior of nuclides, with implications for radiological impact and of significance to collective dose assessment.

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

Measurements of $^{129}$I in air filters, water, and biomass samples from Japan have been carried out working in collaboration with institutions and universities in Japan.

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

４．Necessary technologies to be developed (Example)

We would welcome the opportunity to contribute our expertise and facilities in partnership with companies and institutions in Japan.

５．Notes

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Measurement Device/ Transport Device |
| Title | Real Time Mobile Radiometric Mapping and Analysis |
| Proposed by | Scottish Environmental Research Centre (SUERC) & University of Glasgow School of Physics and Astronomy |

１． Description of the Technology (Features, Specifications, Performance Capability, etc.)

Researchers from the from the Scottish Environmental Research Centre working in collaboration with researchers in the University of Glasgow have developed a unique capability for conducting airborne gamma spectrometry (AGS) and vehicular radiometric surveys . Research into survey techniques and calibration procedures including Monte Carlo simulation has been conducted over the past 30 years. More than twenty environmental surveys have been completed in the UK and overseas, including studies of the majority of UK nuclear sites. Radiometric surveys and particularly AGS are increasingly recognized as being of crucial significance to nuclear emergency response.

Radiometric survey capability includes:

- Aerial and vehicular radiometric surveying equipment and expertise.
- Gamma-ray spectrometer calibration pads.

Our Ground based and airborne detector systems can operate at a range of special scales and can quantify, map and visualize activity inventories per unit area for:

- targeting and evaluating remediation;
- analysis of ecological and agronomic pathways
- dose rate apportionment and dose assessment

２． Past experience (plants in Japan, overseas plant, applications in other industries, etc)

We have 30 years of experience in airborne vehicular and ground-based radiometric monitoring, having delivered much of the UK Chernobyl and nuclear site base-line characterization, and coordinated European projects to harmonize and validate airborne radiometric method development at international level.

At the Fukushima we have already carried out exploratory surveys within and beyond the exclusion zone. We already work with several Japanese institutions and are ready to engage further with Japanese teams.

３． Basis for determining the technology is applicable to Fukushima Power Plant and

technical challenges

Our detector technology has already been tested in-situ at internationally recognized calibration sites in the UK and the Fukushima prefecture in Japan.

４．Necessary technologies to be developed (Example)

The main radiometric mapping and visualization tools are ready for application services within suitable projects and partnerships. We have the developmental capabilities of establishing and modeling directionally collimated detector arrays incorporating real time spectral analysis and intelligent alarms, suitable for operation on manned and remotely operated platforms in a range of environments. The advanced software features could be linked with external equipment, for example remote controlled mobile platforms for exploring contaminated environments, or automatic systems for waste classification and sorting. We would welcome enquiries from Japanese partners interested in developing complete systems solutions to future clean-up challenges, and from partners interested in incorporating established systems into their operational services,

５．Notes

Please also see the attached supporting documents and the following http://khjosen.org/1st_con_fukushima/sympo/20120519s3.pdf

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Decommissioning Equipment |
| Title | Foamed Grout to support decommissioning activities |
| Proposed by | Westlakes Engineering |

１．Description of the Technology (Features, Specifications, Performance Capability, etc.)

*The use of foamed grout as a medium in decommissioning projects is novel in nature, especially the use of foamed grout to stabilise vessels within a radiological cell. Foamed grout is usually used to backfill disused mines and voids and is normally used with higher densities of between 1000 - 2000 kg/m3. and in environments where the performance of the material is less critical.*

*Westlakes Engineering developed and deployed a foamed grout with a density of 300 kg/m3 w to secure redundant chemical process vessels which were at risk of collapse in a hazardous nuclear environment.*

*Foamed grout can be used to remotely to safely and effectively stabilise and shield vessels within a nuclear environment where man access has been precluded due to the structural condition and radiological characteristics.*

*Foamed grout can be used on plant with complex and interdependent constraints including*

- *No Man Access*
- *Heavily Congested Outcell Areas*
- *Poor / Unknown structural performance of building*
- *Interconnected incell contents*
- *Complex Ventilation System and generally poor depression incell*

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

*Foamed grout has successfully been utilized at Sellafield in the UK, where it was used to stabilize a Highly Active Cell to enable decommissioning operations to recommence.*
*Foamed grout is common within the construction industry where it has been used to backfill mines and voids.*
*Westlakes Engineering have no direct experience of working in Japan, however, we recently attended a UKTI trade mission in December 2012*

３．Basis for determining the technology is applicable to Fukushima Power Plant and

| |
|---|
| technical challenges<br>*This technology could be remotely deployed and utilised to stabilize plant, vessels and equipment to facilitate man access to support decommissioning operations. The foamed grout has shielding properties, which would further enhance it use to support operations at this plant.* |
| ４．Necessary technologies to be developed (Example)<br>*The Foamed grout will need to be developed for the specific characteristics of the challenge faced at Fukishima* |
| ５．Notes<br>*A reference from the Sellafield Project Manager, who was responsible for the stabilization of the High Active Cell is appended to this submission.* |

［Format 2］

| Technical Catalog | |
|---|---|
| Category | **Nuclear Waste Management, Spent Fuel Management, Decommissioning, Nuclear Engineering and Consulting** |
| Title | See above |
| Proposed by | **NUKEM Technologies GmbH** |

１．Description of the Technology (Features, Specifications, Performance Capability, etc.)

- **Nuclear Waste Management**: spectrum from concept development to turn-key projects; technical details please refer to our company presentation attached.
- **Spent Fuel Management**: technologies for characterization of spent fuel elements; handling facilities; classification systems for defective fuel; different kinds of storage technologies.
- **Decommissioning**: decontamination and clearance measurement technologies; in-situ segmentation of RPVs, dismantling up to “greenfield”.
- **Nuclear Engineering and Consulting**: process and mechanical design solutions; safety assessment and licensing support; technical documentation; radiation measurement systems.

２．Past experience (plants in Japan, overseas plant, applications in other industries, etc)

**For detailed references please refer to our attached company presentation.**

３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges

**NUKEM’s references and gained technological experiences in various successfully executed international projects.**

４．Necessary technologies to be developed (Example)

**Please refer to item 4 above. Each project executed by NUKEM required a tailor-made technical solution or a combination of different technologies.**

５．Notes

**None**

［Format 2］

| Technical Catalog | |
|---|---|
| Category | Example: Transportation Equipment/ Working Equipment/ Measurement Device/ Support Device/ System |
| Title | |
| Proposed by | Rosemary Jones（書式未記入） |
| １．Description of the Technology (Features, Specifications, Performance Capability, etc.) | |
| ２．Past experience (plants in Japan, overseas plant, applications in other industries, etc) | |
| ３．Basis for determining the technology is applicable to Fukushima Power Plant and technical challenges | |
| ４．Necessary technologies to be developed (Example) | |
| ５．Notes<br><br>Please place a check mark to identify that this technology is either in:<br>☐ a research and development phase or ☐ a practical application phase. | |