[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Inspection and Repair
Title	Nuclear Remote Inspection and Repair Device
Proposed by	Westinghouse Electric Japan

1. Technical description (Advantage, Specification, Performance)

Westinghouse wholly owned subsidiary WesDyne

PWR Vessel Inspection Services

VESSEL – NOZZLE – PIPING

SUPREEM™

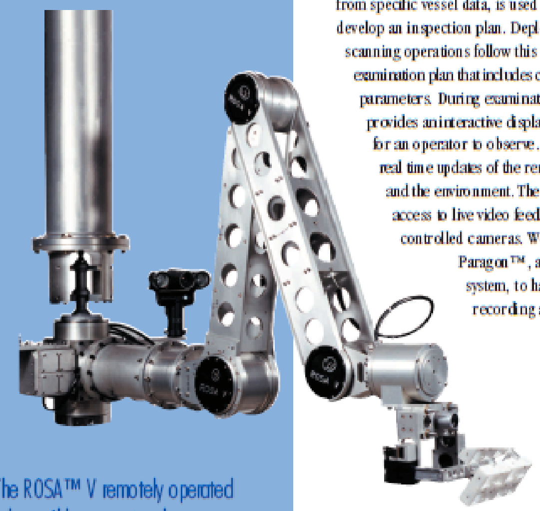
WesDyne inspected a 4-Loop PWR in
2.9 days.

WesDyne inspected a 3-Loop PWR in
2.4 days.

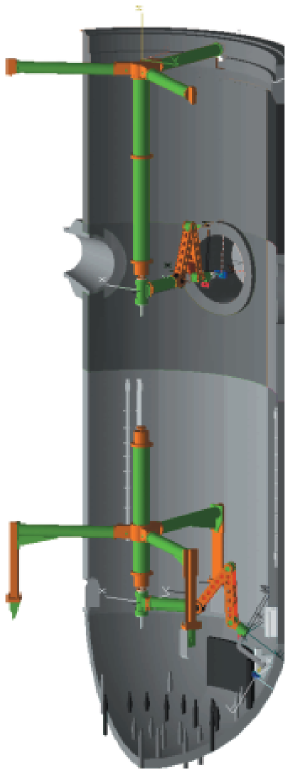
WesDyne's PWR inspection system is
EPRI/PDI qualified.

WesDyne uses the Submersible Platform with ROSA™ End Effector Motion (SUPREEM™) to examine PWR vessel bottom head welds, nozzle to shell welds from the shell surface, nozzle to shell welds from the bore and pipe ID welds. The SUPREEM™ has a number of features that offer the benefit of reduced examination time. It has two platforms with robotics on each to conduct two separate operations simultaneously. It uses an efficient, compact and lightweight design along with a modular construction to make set up and take down quick and easy. As another benefit, the SUPREEM™ has minimal impact on other service operations. It does not need a large laydown area and it requires minimal use of the equipment hatch and the polar crane.

An integral part of the SUPREEM™ examination system is the ROSA™. With six axes of motion, the ROSA™ uses remote docking to ensure reliable, accurate, and repeatable inspections. Remote operation of the ROSA™ is computer monitored and controlled. A computer 3D model, constructed from specific vessel data, is used as a simulator to develop an inspection plan. Deployment and scanning operations follow this pre-programmed examination plan that includes collision avoidance parameters. During examinations, a computer provides an interactive display of the 3D model for an operator to observe. Sensors provide real time updates of the remote robotic units and the environment. The operator also has access to live video feedback via remotely controlled cameras. WesDyne uses the Paragon™, a dual Pentium PC system, to handle the data recording and processing.



The ROSA™ V remotely operated submersible apparatus does simultaneous **UT detection and sizing operations.**



Computer model of SUPREEM™ platforms with ROSA™

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.) Westinghouse designed the first 4 PWRs in Japan. More recently, Westinghouse designed the equipment and cut out Reactor Coolant Piping at Tomari Nuclear Plant. In addition Westinghouse has designed, built and repaired nuclear plants all over the world. Westinghouse based nuclear plant design is used in approximately one half of the worlds nuclear plants.
3. Applicability to Fukushima site, Technical challenges Limited access openings. The radiation environment is not a significant obstacle as we design and operate equipment in similar environments.
4. Technology Development (Example) Modification of equipment to apply extensive Westinghouse portfolio of remote machining and repair (welding, clamping, plugs, memory metal, etc.) through the available PCV access openings and through access openings which can be made by our remote machining equipment.
5. Note

[Format 2-3] Session2: Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Remotely Controlled Travelling Mechanism
Title	Submersible Decommissioning Remotely Operated Vehicle
Proposed by	SMD Robotics Limited

1. Technical description (Advantage, Specification, Performance)

The purpose of the Submersible Decommissioning Remotely Operated Vehicle is to perform remote decommissioning tasks, where it is impossible or undesirable to deploy a human operator due to the hazardous nature of the working environment. With a range of tooling options available the D-ROV is not only versatile to meet customer requirements, but comes with over 40 years of reliable subsea engineering experience.

Constructed from standard SMD Curvetech® components the D-ROV has been designed to be easily maintainable, reliable and compact to perform underwater activities such as inspection, size reduction, debris removal, ground clearance, dredging and pre-installation landscaping of customer sites. The D-ROV can be supplied as a versatile standard vehicle or tailored to meet a specific customer requirement.

In addition to the extensive range of tooling attachments that can be mounted on the D-ROV, it is also capable of accepting standard robotic manipulators to give finer dexterity of remote tasks.

D-ROV incorporates several key features that help tackle the variety of activities when performing underwater decommissioning:

- Simple articulated arm – The robust structure with minimal component count ensures maximum performance and reliability.
- Remote Quick-hitch mechanism – The optional quick-hitch mechanism enables tools deployed from the articulated arm to be remotely exchanged without the necessity to recover the vehicle to the surface or safe working area.
- Standard components – The D-ROV utilises standard SMD Curvetech® components found on many SMD WROV's and TMS's. The utilisation of standard components ensures proven reliability, technical compatibility, minimal operator training and easy access to technical

support and replacement parts.

Description	Specification
Maximum overall dimensions	1300mm (width) x 2000mm (length) x 1000mm (height)
Maximum Est. Gross Weight	1500 kg.
Estimated payload	150 kg
Operating Temperature	-10ºC to +45ºC
Construction	Carbon Steel frames with either aluminium or stainless steel sub-assemblies. High quality marine paint finish suitable for long term submerged operations. All hydraulic fittings Stainless Steel (JIC/Swagelok).
Hydraulic power	Curvetech® Power pack: - 4 Pole, 8.5 kW (11.5 HP), nominal 3000Vac, 60 Hz. - One primary hydraulic pump.
Ground Speed	0.5 m/s (1.8km/h – 1 knot)
Depth rating	3000 msw.
Control system	DVECS2.
Video capability	Three simultaneous channels, composite format.
Lighting capability	Interface for six (6), 30W, 24Vdc LED lamps
Sensors/Alarms	Oil reservoir volume, System oil pressure, Hydraulic oil temperature, Compensator level, Water ingress, Depth & Heading
Incoming power supply	415Vac, 3∅+E, 50Hz supply.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

No application to actual plants. The D-ROV system has been proposed to Sellafield Limited to assist with decommissioning of the First Generation Magnox Storage Pond.

3. Applicability to Fukushima site, Technical challenges

Applicable issue	Applicability	Remarks and reasons (quantitatively)
Usability in a radioactive environment	YES	Design/specification option for being operated in a radioactive environment.
Remote handling equipment that loads decontamination system and allows decontamination	YES	The system is a remotely controlled vehicle capable of being fitted with a variety of tools, sensors and decontamination equipment.

4. Technology Development (Example)

Developments to enhance the capabilities of the Submersible Decommissioning Remotely Operated Vehicle may include:

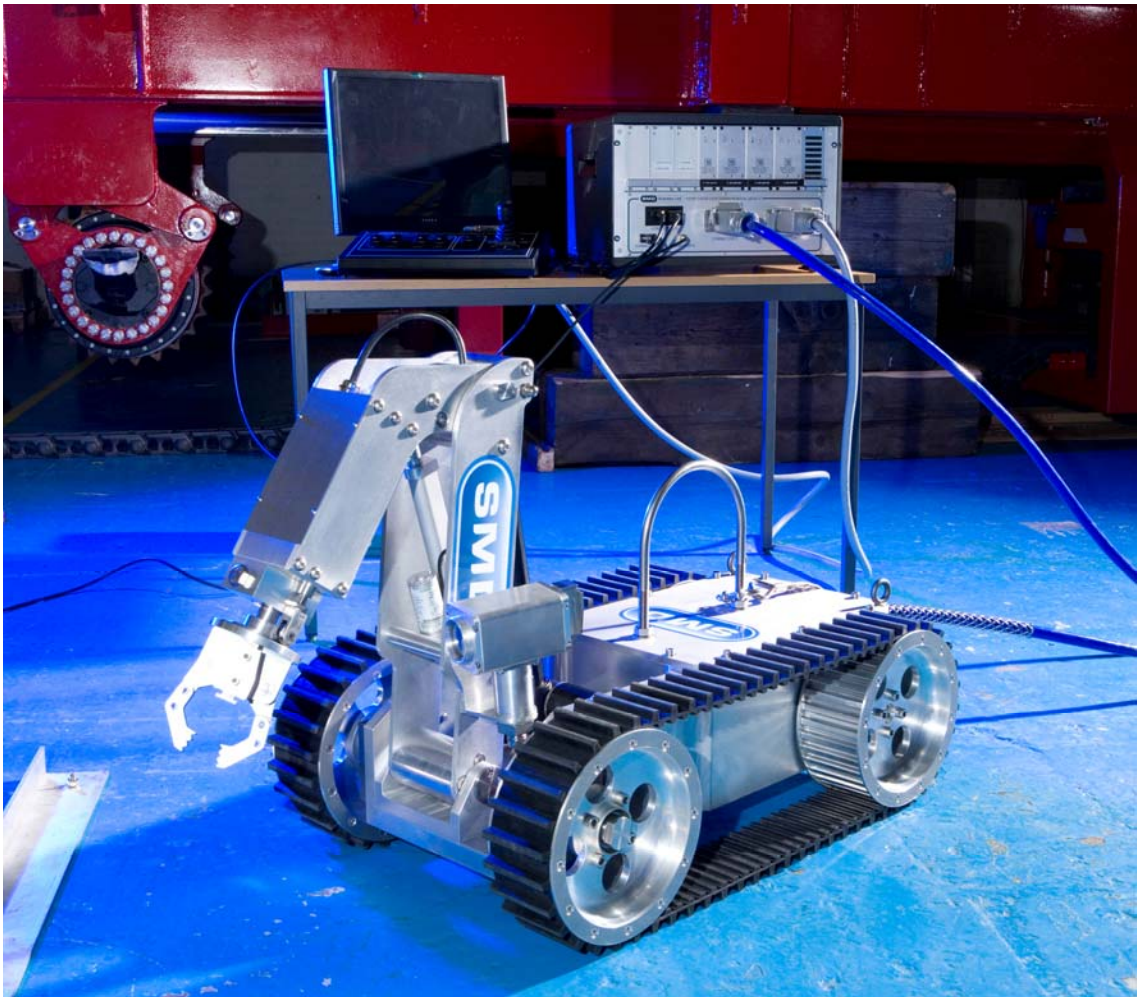
• Integration of additional sensors (environment, vision, dose up-take, etc.). • Integration of preferred decontamination equipment (scabbler, water spray, dredge, etc.). • Development of cable/hose management systems (to enhance deployment/recovery operations).
5. Note The design and specification of the SMD Submersible Remotely Operated Vehicle may be revised to modify its physical size, weight, payload and operational/task functionality to meet the specific requirements for Debris Removal Preparation at TEPCO Fukushima Daiichi Nuclear Power Plant.

[Format 2-3] Session2: Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Remotely Controlled Travelling Mechanism
Title	Debris Clearance Vehicle
Proposed by	SMD Robotics Limited

1. Technical description (Advantage, Specification, Performance)

The purpose of the Remotely Operated Ground Vehicle is to perform remote intervention tasks, where it is impossible or undesirable to deploy a human operator due to the hazardous nature of the working environment.



The vehicle is a self-propelled tracked vehicle, of simple complexity to ensure maximum reliability, capable of climbing stairways and traversing uneven surfaces with ease.

The vehicle is built around an aluminium alloy body that is used to house and shield the internal components.

The propulsion drive system comprises of a pair of motors. Steering of the vehicle is provided by the differential speed and direction of two tracks, thereby enabling the vehicle to turn in a small working area.

The vehicle is provided with a simple rate controlled articulated arm capable of picking up objects with payloads weighing 17kg. The articulated arm is supplied with a remotely detachable continuous jaw rotate assembly, the speed of which is adjustable. The jaw assembly is designed to grip objects with sufficient force to ensure that they will not be dropped during normal or failure conditions.

The vehicle is supplied with a colour zoom camera that is installed in a fixed position on the side of the articulated arm and ensures good visibility of the working area for the operator. The camera is designed to enable it to be remotely replaced, while operating in the hazardous working environment. To facilitate this, the camera is fitted with a special connector system.

Description	**Outline Specification**
Maximum overall dimensions	550mm (width) x 950mm (length) x 600mm (height)
Maximum Gross Weight	116.5 kg.
Drive	Two independent track assemblies each actuated by a geared dc brushed motor.
Articulated arm	Simple electric actuator driven articulated arm complete with endless rotation.
Ground Speed	0.3 m/s (1 km/h)
Control system	No onboard electronics fitted. All control motors are hard wired. Operator control station located in a safe working area.
Camera	Non radiation hardened colour zoom camera. Optional radiation hardened camera available.
Operator Control	Controls for: - Vehicle drive (forward/reverse/turn control) - Articulated arm - Camera
Video Monitor	A desk seated 17” video monitor.
Incoming power supply	240Vac, 1∅+E, 50Hz supply.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

The Debris Clearance Vehicle has been operated in the Shear Cave of the Thermal Oxide Reprocessing Plant at the Sellafield nuclear license site in Cumbria, U.K. The vehicle has been used to collect and transfer irradiated fuel elements to a storage container within the plant. The radiation field within which the vehicle is operated is 500 mSv/h to 10 Sv/h.

3. Applicability to Fukushima site, Technical challenges

Applicable issue	Applicability	Remarks and reasons (quantitatively)

Usability in a radioactive environment	YES	Currently being operated in a radioactive environment at Sellafield nuclear license site with radiation field up to 10 Sv/h.
Remote handling equipment that loads decontamination system and allows decontamination	YES	The system is a remotely controlled vehicle capable of being fitted with a variety of tools, sensors and decontamination equipment.

4. Technology Development (Example)

- Developments to enhance the capabilities of the Debris Clearance Vehicle may include:
- Integration of additional sensors (environment, vision, dose up-take, etc.)
- Integration of preferred decontamination equipment (scabbler, water spray, dredge, etc.)
- Development of cable/hose management systems (to enhance deployment/recovery operations)

5. Note

The design and specification of the SMD Debris Clearance Vehicle may be revised to modify its physical size, weight, payload and operational/task functionality to meet the specific requirements for Debris Removal Preparation at TEPCO Fukushima Daiichi Nuclear Power Plant.

[Format 2-3] Session2 - Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	**GENERIC**
Title	**TECHNICAL SUPPORT TO TEPCO FOR INSPECTION EQUIPMENT IN HEAVY RADIATION FIELD**
Proposed by	**IFE – OECD HALDEN REACTOR PROJECT**

1. Technical description (Advantage, Specification, Performance)

    a) In collaboration with TEPCO, review of proposals equipment and technical solutions, aiming to identify
        - weak and strong points with proposed equipment or solutions
        - required testing/ verification/ demonstrations to qualify the proposal
        - specification of upgrades required
        - range of practical applicability

    b) Where applicable, design and fabrication of parts, cabling, equipment for supporting the remote-control measurements

    c) Production of ad-hoc, miniaturized, remotely operated sensors, tailor-made for specific types of measurements

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

    a) More than 50 year experience with in reactor measurements, including a number of in-core remote operations in a very limited space, at high temperature, and in a heavy radiation environment

    b) Well known in Japan due to long-term collaboration with Japanese institutions and industry, including TEPCO, Hitachi, Toshiba, Mitsubishi

    c) Delivery of tailor-made sensors to nuclear institutions in Japan and Europe (gamma thermometers, pressure transducers, flow meters, level gauges, electrochemical potential)

    d) We have skilled Japanese personnel among our staff

3. Applicability to Fukushima site, Technical challenges

    We believe that all our experience is directly applicable to Fukushima

4. Technology Development (Example)

    See PPT attachment

5. Note

2. FORMAT

Northrop Grumman Remotec is pleased to submit this proposal for remotely controlled equipment to assist in the decontamination of sites and equipment. Northrop Grumman Remotec has a long history of designing, manufacturing, integrating and supporting a wide range of Robotic Systems including the Andros line of Hazardous Duty Robotic Systems and Andros Heavy Duty Remote Controlled Equipment. Northrop Grumman Remotec is the supplier of choice for both civilian and military 1st responders worldwide.

Format 2.2 Remote Control Technology for Decontamination Work

Northrop Grumman Remotec manufactures a variety or production, off the shelf equipment suitable for Decontamination applications. Vehicle sizes ranges from 55 kg to 370 kg. Please the attached brochures for the full line of Andros Hazardous Duty as well as Andros Heavy Duty Vehicles.

[Format 2-2] Session1: Remote-control decontamination

Technical Catalogue	
Mobile device classification	Unmanned Ground Vehicles
Title	Andros and Andros Heavy Duty Remote Control Equipment
Proposed by	Northrop Grumman Remotec

1. Technical description (Advantage, Specification, Performance)

Northrop Grumman Remotec has a long history of designing, manufacturing, integrating and supporting a wide range of Robotic Systems including the Andros line of Explosive Ordnance Disposal (EOD) robots. Northrop Grumman Remotec is the supplier of choice for both civilian and military 1st responders worldwide.

Please attached documents for detailed specifications and accessories.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Remotec Northrop Grumman has operated in hazardous environments for over 30 years including Nuclear facilities, power production, chemical factories and various Military and Law Enforcement applications

3. Applicability to Fukushima site, Technical challenges Andros Robotics could be deployed to great effect at Fukushima for monitoring, sampling decontamination and equipment utilization.
4. Technology Development (Example) All Andros products are mature and in production.
5. Note Northrop Grumman Remotec maintains an international Sales force and is compliant with all ITAR regulations

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Manipulation
Title	DADM, Dual Arm Dexterous Dual Arm Manipulator 3D
Proposed by	Remotec Northrop Grumman
1. Technical description (Advantage, Specification, Performance) The Andros Dual Armed Dexterous Manipulation (DADM) system is a highly dexterous	

manipulation system designed to enable a remotely located operator to perform fine manipulation tasks such as unzipping a bag, delicately moving small objects, or cutting small wires. The system consists of two major components; the DADM platform and the operator controller. The DADM platform consists of two highly dexterous 8 degree of freedom manipulators joined at a common body. The configuration approximates the scale and movements of a human and is therefore very intuitive and easy to operate. The operator controller consists of a similarly configured set of arms that are held by the operator. In order to move the remote arm, the operator grasps the controller and moves and grips as one would use their own arms and hands. The remote slaved DADM mimics the movements of the controller. This type of master/slave control is extremely intuitive and has proven to yield excellent results with minimal operator training.

The DADM platform also features an integrated tool caddy which contains three (3) removable tools: (1) powered wire cutter, (1) passive nylon strap cutter, and (1) powered screwdriver. The operator can remotely open the tool caddy and pick up a tool with the DADM gripper to expand the capability of the system. When use of the tool is complete, the operator can remotely place it back into the tool caddy and resume work with the normal gripper.

		DADM Unit	**Operator Controller**

Physical			
	Size (Est.)	(Folded) 15"x24"x6.25"	15"x20"x5"
	Weight (Est.)	25 lbs.	15 lbs.
Interface			
	Communications	Dedicated 50' Tether	Dedicated 50' Tether
	Power	BB2590	AC Outlet 110/220V, USA format
	Video Format	Dual HD-SDI, 1080p 30 NTSC video	Dual HD-SDI, 1080p 30 NTSC video
Performance			
	Arm Degrees of Freedom	8 per arm	8 per arm
	Arm Length	20"	N/A
	Arm Lift, Full Extension (Est.)	4 lbs per arm	N/A
	Vision System	Stereo HD cameras full resolution, 30fps	Stereo heads down display, HD resolution, 30fps

Environmental		Laboratory Use Only	Laboratory Use Only

Table A - Key Specifications

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

NA

3. Applicability to Fukushima site, Technical challenges

The DADM would allow for remote operations requiring very fine, Human like control.

4. Technology Development (Example)

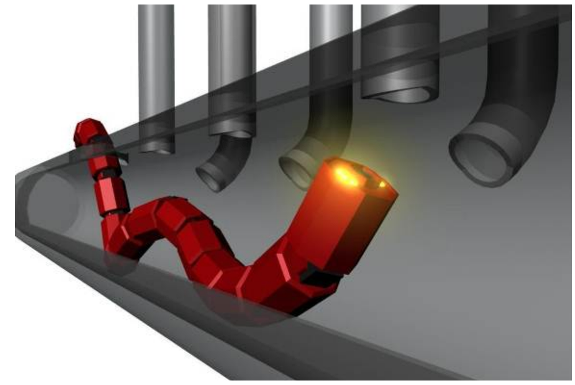
TRL 6, currently planned for production 2013

[Format 2-3] Session2

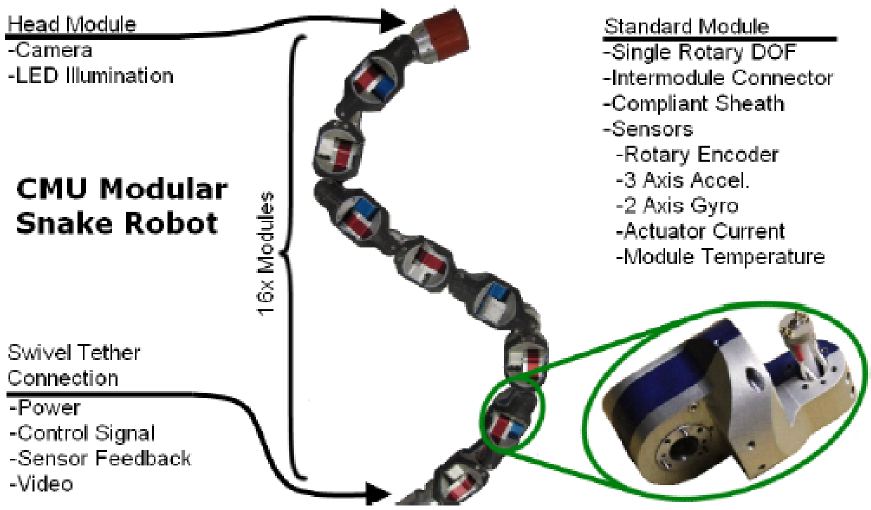
Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Traveling Mechanism (including Working Device)
Title	Modular Snake Robot
Proposed by	Carnegie Mellon University Biorobotics Lab

1. Technical description (Advantage, Specification, Performance)



Snake robots are long and slender devices with many internal degrees of freedom which they can use to thread through tightly packed volumes accessing locations that people and machinery otherwise cannot use. They have the potential to navigate in highly confined and unstructured terrains not permissible to conventional wheeled and tracked robots For example, snake robots can navigate both inside and outside of networks of pipes. Snake robots are capable of operation underwater and in high temperature environments. Due to the small size and weight, the robot can be deployed by several different means, including other mobile robots, or human porters. Weight: 2.9 kg. Dimensions: 5.1 cm diameter x 94 cm length.



2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

The Modsnake has been used in power plants in the USA and search and rescue simulations.

3. Applicability to Fukushima site, Technical challenges

Applicable Issue	Applicability	Remarks and reasons (quantitatively)
Usability under a radioactive environment	Unknown	To be tested in radioactive environment, but many components are rad-hard
Usability in a high temperature environment (60°C)	YES	Rated to function in up to 80°C.
Underwater operation	YES	Operation at depths up to 3 meters; ability to swim underwater by undulating body of robot.
Access to inside of pedestal	YES	Able to self-travel on floors as well as around rubble and through packed volumes/confined spaces. No other snake-like or borescope robot can reach more than 5 meters; ours can go a much greater length
Application to narrow spaces	YES	Outer diameter is 51mm.
Investigation of position/status of fuel debris	YES	Contains camera on head of snake robot.
Correspondence to the disclosure of technical information/remodeling	YES	Customization according to intended purpose is possible.
Dispatch of operation engineers	YES	Dispatch to Fukushima Daiichi Nuclear Power Station is possible.

4. Technology Development (Example)

Development to include additional sensors which may be useful in the desired environment

.

Development is necessary to test radioactive compatibility and harden the device to radiation and improve operation in high temperature environments.

5. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	**Inspection Equipment (Specially required technology)**
Title	**Radiation tolerant video camera**
Proposed by	**Centronic Limited**

1. Technical description (Advantage, Specification, Performance)

Video camera capable of operating in radiation environments

*Dose rate up to:**10E6 rad/hr***

*Total dose up to: **10E8 rad/hr***

*Environmental tolerance: **IP68***

*Technology: **video tube***

*Accessories: **pan & tilt, LED lighting, lenses, wipers, control systems***

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Nuclear power plant and fuel processing facilities in Japan and worldwide

3. Applicability to Fukushima site, Technical challenges

Development of Investigative Technology for Inside Containment Vessels

Applicable issue	Applicability	Remarks & reasons
Usability in radioactive environment	YES	Tested to 10^6 rad/hr up to 10^8 rad total dose
Usability in (60') temperature	POSSIBLE	A cooling jacket is sometimes used
Access to inside of pedestal	NO	Combination with a robot or manipulator is required
Investigation of position / status of fuel debris	YES	This is a vision device
Correspondence to the disclosure of technical information & remodelling	YES	Our original design Engineers presently support the product
Dispatch of operation Engineers	NOT REQUIRED	On-site support may be negotiated if necessary

4. Technology Development (Example)

It is necessary to combine the camera with a robot or static mounting position. Centronic can offer assistance with this.

5. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	**Inspection Equipment (Specially required technology)**
Title	**Radiation detectors (neutron-gamma probe)**
Proposed by	**Centronic Limited**

1. Technical description (Advantage, Specification, Performance)
   - ***Combined neutron-gamma radiation detector probe and associated electronics***
   - ***Based on 20 units designed and supplied to the New Safe Containment for Unit 4 Chernobyl Nuclear Power Plant.***
   - ***Rugged design of probe assembly, preamplifier and cabling to reside in "prohibitive" spaces: IP65 rated (water/moisture ingress and washdown resistant) and operable under gammas of 0.6MeV and thermal neutron fluence of 1E+11 nv***
   - ***Expected service life of 30 years***
   - ***Probes to be inserted into boreholes drilled into several shelter wells***

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Type tested, 20 probes presently on-site at Unit 4 Chernobyl Nuclear Power Plant

3. Applicability to Fukushima site, Technical challenges

Development of Investigative Technology for Inside Containment Vessels

Applicable issue	Applicability	Remarks & reasons
Usability in radioactive environment	YES	Testing can be adapted to match the anticipated environment
Usability in (60') temperature	YES	Experience includes "high temperature" detectors used in UK AGR reactor control channels
Access to inside of pedestal	NO	Combination with a robot or manipulator is required
Investigation of position / status of fuel debris	YES	This is a rugged radiation measuring sub-system
Correspondence to the disclosure of technical information & remodelling	YES	Our Engineers would expect to work closely with the customer
Dispatch of operation Engineers	NOT REQUIRED	Unlikely to be needed

4. Technology Development (Example)

It may necessary to combine the camera with a robot or static mounting position. Centronic can offer assistance with this.

5. Note

[Format 2-3] Session 2　Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	
Title	Remote Controlled Vehicle (Crawler) to analyse situation in hazardous environment
Proposed by	NUKEM Technologies GmbH

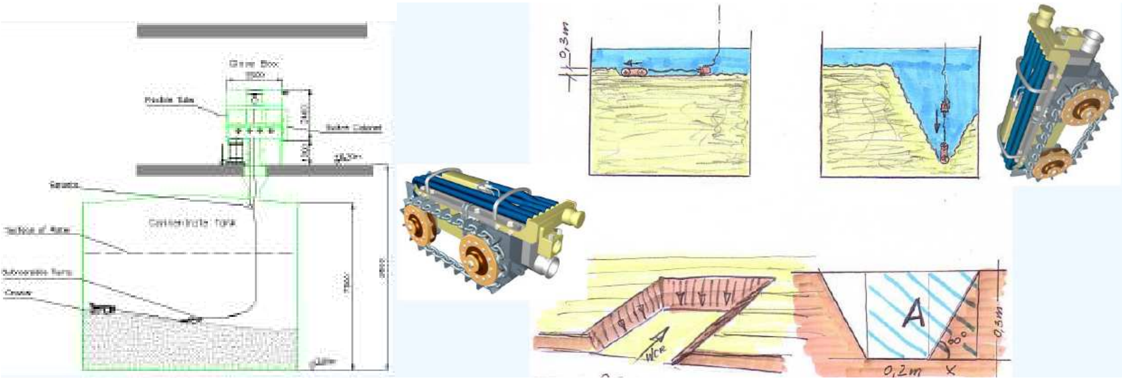
1. Technical description (Advantage, Specification, Performance)

The Crawler was designed and operated to remove

- crystallised salt,
- liquid RAW,
- sludge,
- IEX-resins

from collection tanks at Kola NPP (Russia).

Photo of Crawler



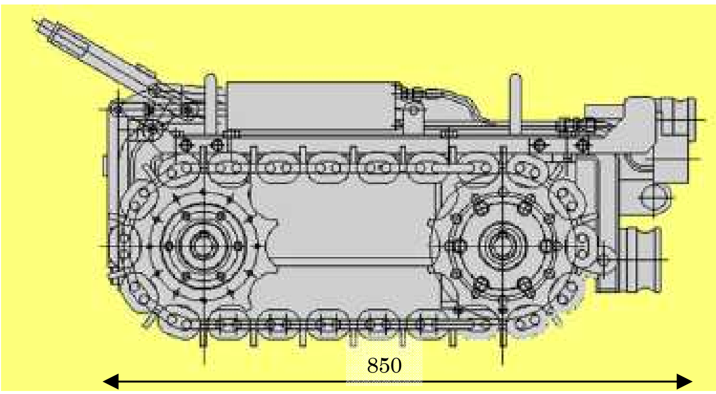
Working Principle

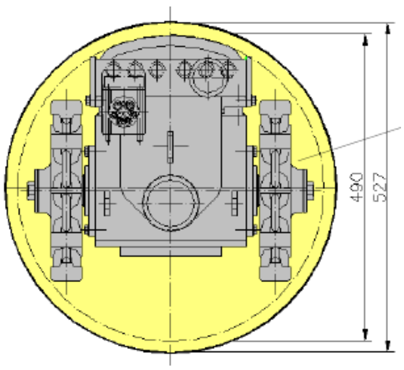
The Kola-Crawler was equipped with

- a pump to suck and pump the liquid solution
- 4 wheels and 2 pairs of chain
- an intake to suck the liquid solution
- jets to spray the liquid solution onto the surface to re-dispense salt or sludge or particles that they can be removed
- light and camera for observation

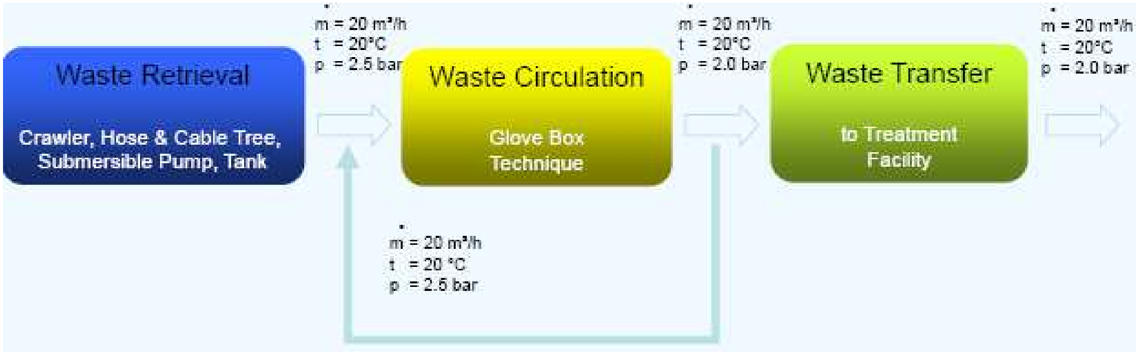
Moving is performed by the 2 chains which are powered by compressed air. Each pair of wheels is powered separately to enable direction changes.

To remove the crystallised evaporator concentrates (salt) from the collection tanks, the salts had to be re-dispensed. Therefore the liquid solution was re-circulated and heated. Heating as well as pH-adaptation was performed in a glove box. The glove box also served as a lock to move the crawler into the tanks and after execution to pack it free of contamination via a lock into a 200 liter drum.





The processing of the “Kola Crawler” is outlined in the following scheme:



The Kola-Crawler can be used to remove

- liquids (liquid RAW and others)
- sludge and sediments
- crystallised salt

from areas, floors, rooms.

Modified versions of the Crawler also can be operated as remote controlled

- vacuum cleaner to remove dry sediments/particles from floors and walls
- high pressure water jet cleaner to remove soft and hard adhesion contamination on floors and walls
- **inspection and sample device to analyse in-situ situations in hazardous environments.**

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

The Crawler was successfully operated at Kola NPP (Russia) to empty and to clean collection tanks containing

- crystallised salt,
- liquid RAW,
- sludge,
- IEX-resins

The operation of the Crawler is shown in a video. Please refer to chapter “Note” in format 2-1.

3. Applicability to Fukushima site, Technical challenges

The Crawler mentioned above, can be modified that it can serve as inspection device. Equipped with camera and perhaps a sample device, the modified Crawler can be used to analyse the situation in flooded areas as well as not flooded areas.

It can move on the floor but it cannot cross obstacles.

4. Technology Development (Example)

The Crawler was developed and constructed by NUKEM due to the specific requirements of the specific needs at Kola NPP.
Furthermore NUKEM developed a variety of other techniques due to the specific requirements of its clients.

5. Note

With its experience in the experience of a big number of nuclear projects dealing with decontamination behaviors (operation of Waste Treatment Centers/Facilities and Decommissioning or Dismantling Projects) as well as in the mentioned Kola-project NUKEM has the qualification and is able to modify and adapt its decontamination techniques due to the specific needs (operational and economical) at Fukushima site.

Please refer to www.nukemtechnologies.de for further information and overview of NUKEM´s experience, competence and competition. Don´t hesitate to contact us in case of further questions or further information.

Note furthermore:

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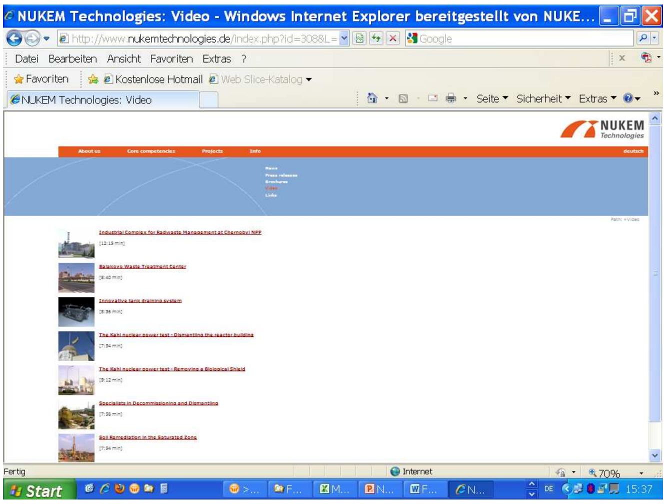
<td>Note

</td>
<td>Reference documents:
• Crawler video

For further information please refer to www.nukemtechnologies.de
Sublink ➡ Info ➡ Video
“Innovative Tank Draining System”</td>
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[Format 2-3] Session 2　Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	
Title	
Proposed by	NUKEM Technologies GmbH, Alzenau, Germany

1. Technical description (Advantage, Specification, Performance)

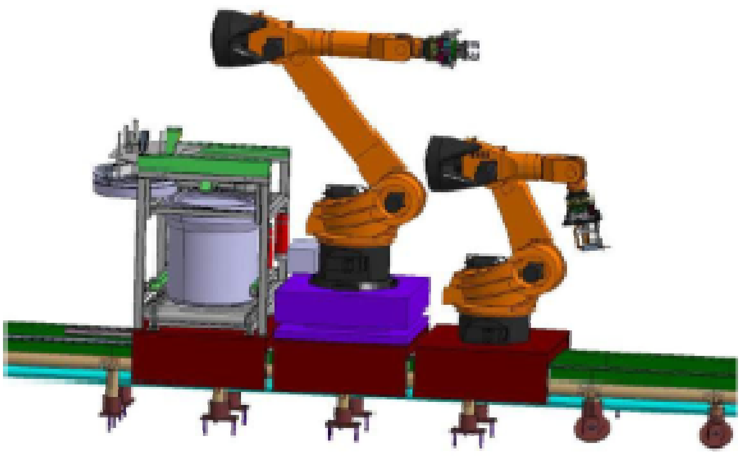
Based on state-of-the-art industrial robot technique Nukem launched in 2009 the design of a universal mobile remote controlled decommissioning and handling system which can be equipped with a variety of special add-on tools and equipment required for the dismantling of reactor core components under severe radiological conditions.

Special features of the unit:

- Running on track, which eases exact global positioning and ensures reproducibility of actions
- Capability to lay its own track (adding-on of track sections) in areas inaccessible to human intervention, this feature allows also to carry out a “progressive forward” dismantling operation into originally inaccessible areas.
- Basic capacity and flexibility of industrial robot enhanced by additional travelling axis (which can be supplemented by additional lifting axis, if required)
- Various exchangeable add-on tools (for mechanical and thermal cutting), standard and special grabs as well as other special devices like vacuum collection system, etc. . These accessories are tailor made for application to the robot hand in order to cope with the different tasks and situations in the ongoing dismantling process
- On-board radiation resistant video camera with microphone and floodlights to give the operators a clear picture of the remote situation
- On-board fire detection and firefighting equipment to cope with possible fire hazards in particularly due to thermal cutting or to heat generating mechanical cutting operations
- Energy and media supply/signal exchange via cable drag chain guided/safely embedded within the track system. Under reverse travelling of the unit there is no danger that the guided energy chain will be run down by the travel mechanism.
- Remote control system for manual and automatic operation including teaching features as well as automatic limitation of movements in pre-determined positions and areas.

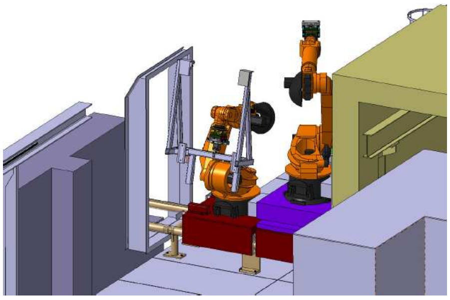
Within the programmed or teached boundaries (clear of obstacles) the unit may carry out movements automatically which eases the control work of remote operators and also considerably speeds up the whole operation.

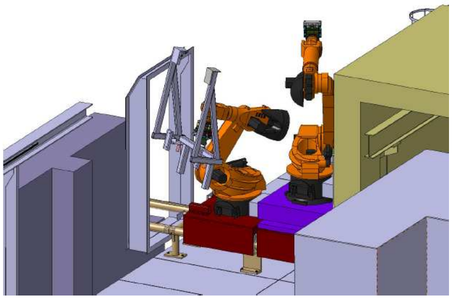
- Possibility to operate two separate units in parallel on the same guiding track, e.g. complex cutting and handling operations requiring mutual assist, splitting of work (e.g. operation of one cutting unit + one collecting unit), etc.. This feature is also of particular value in case of potential recovery situations.
- Possibility to attach a trailer to the robot unit in order to carry a shielded transport container along with which enables the packing and removal of irradiated or contaminated cut and/or collected parts out of the decommissioning zone

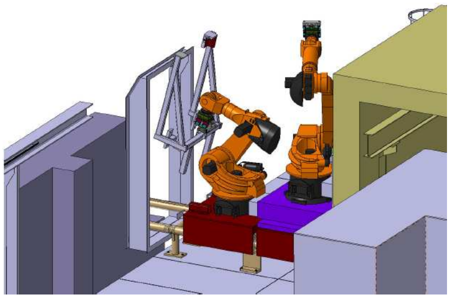


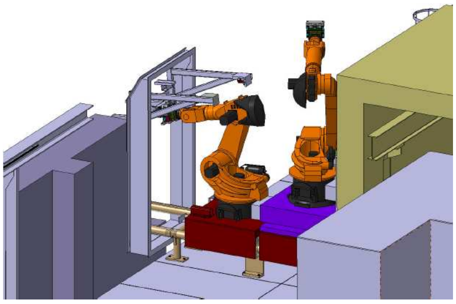
Track-mounted remote operated robot

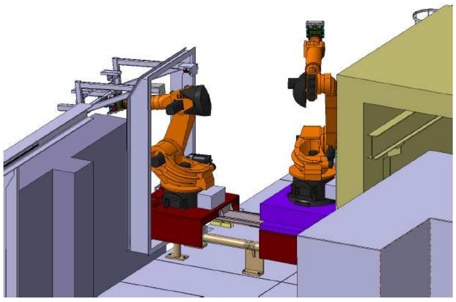
The photo sequence below illustrates the remote operated installation of track sections by the robot itself

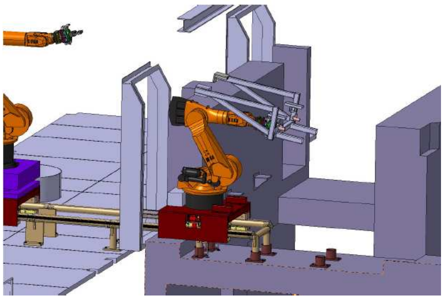


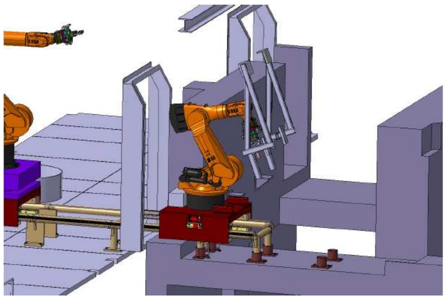


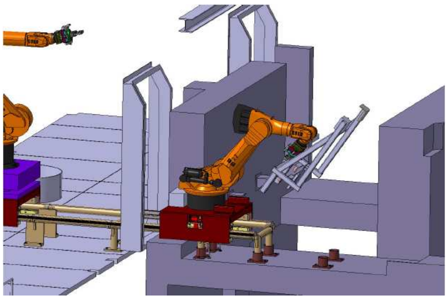


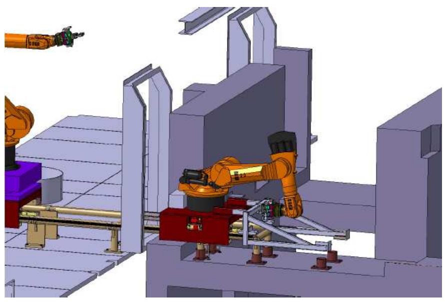


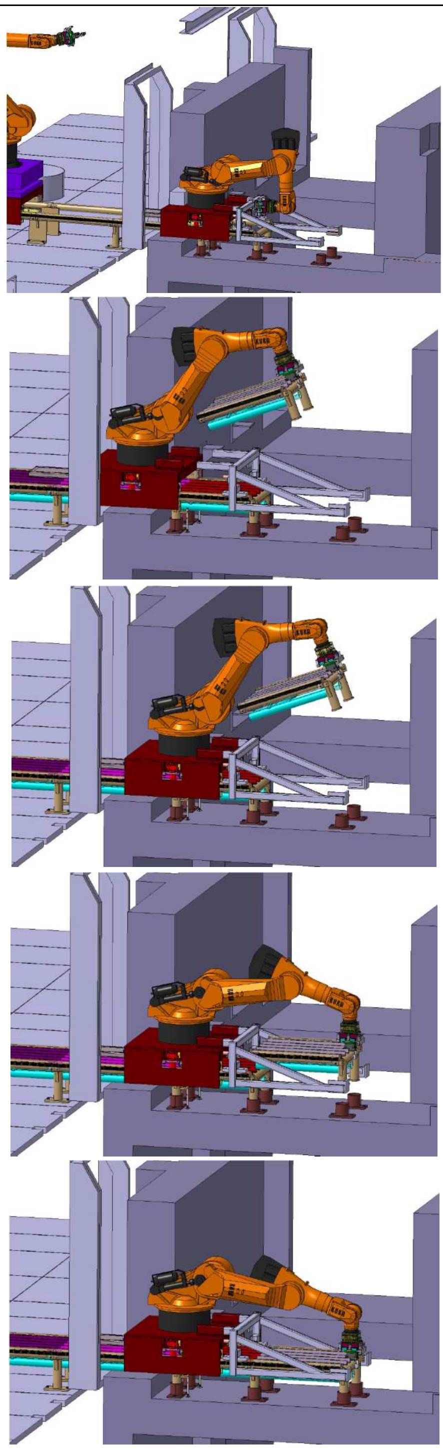




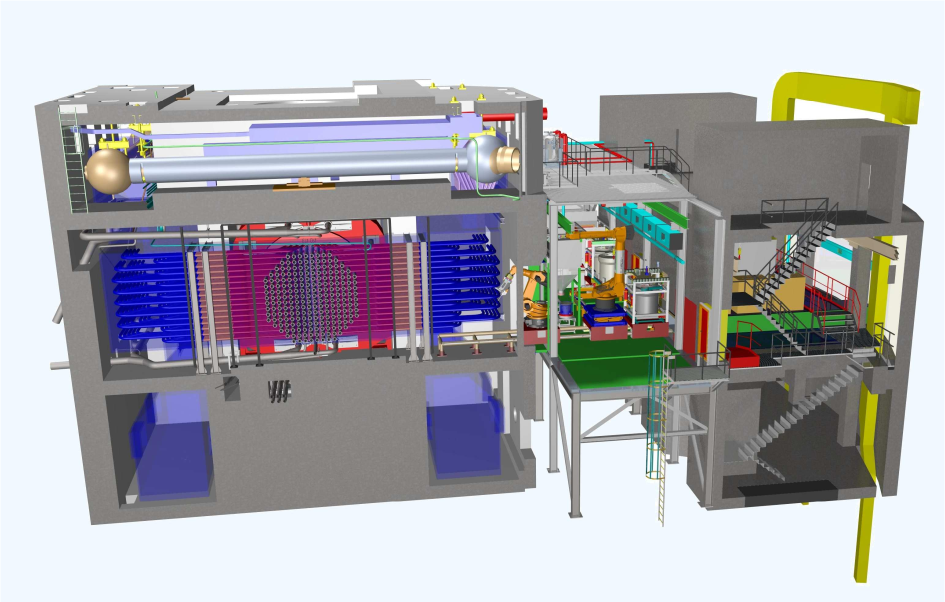


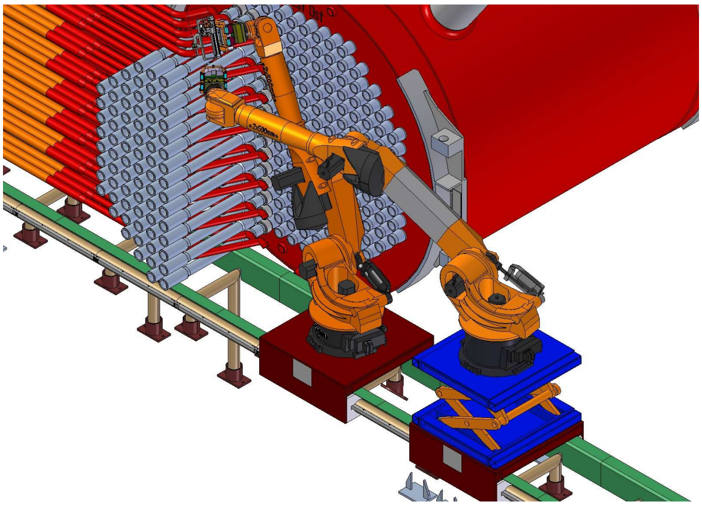


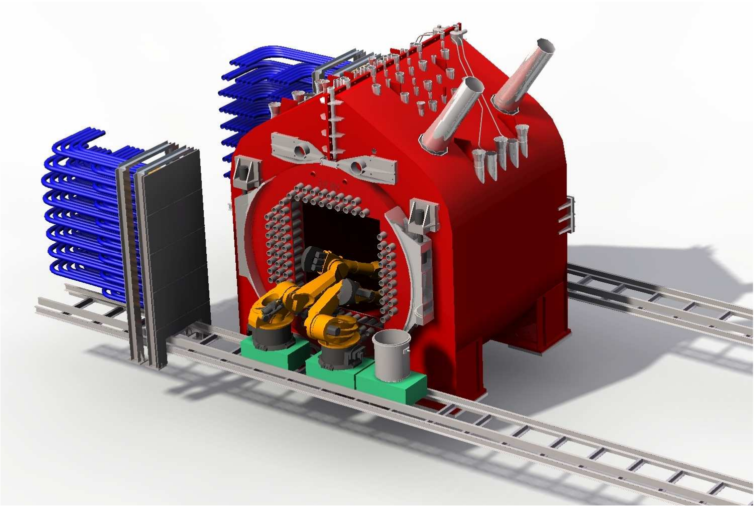


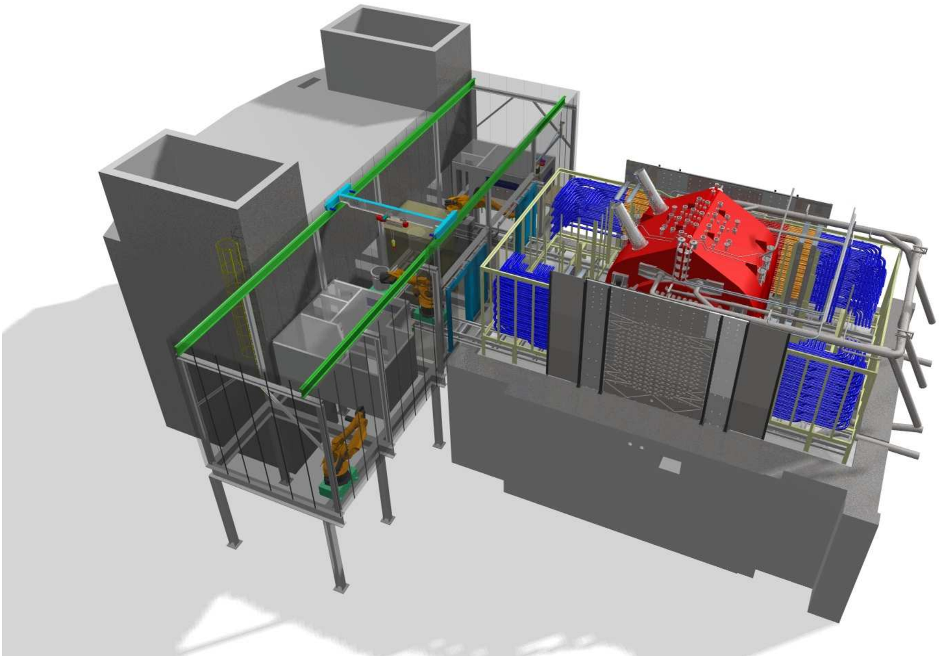


3D-views of the Dismantling Robot and its installations









Integral part of the operational system is a “home base” (housed and shielded area outside the irradiated working zone) where the system will be commissioned at the beginning and where it will return at the end of each operation in order to exchange shielded transport containers and to carry out decontamination, maintenance and repair of the unit(s). The “home base” is divided from the working zone by a shielded door which will only be opened for the passage of the unit.

In the “home base” human intervention to the system is either possible from shielded posts using the glove box technique (for small repair/basic decontamination purposes) or by direct intervention under inherent protection. Human access to the “home base” is possible from the outside via double door locks.

Amongst others the “home base” is equipped with tool exchange racks, handling and service equipment (EOTC-crane, etc.) as well as with material locks for shielded transport containers, add-on track sections, spare parts, etc..

The operator room of the system is installed some 100 meter away of the working zone and is arranged even outside of the reactor building. The operator room is equipped with various MMI’s, the monitors and control desks of the CCTV system as well as instrument displays giving a clear picture of the actual status and conditions.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

As already explained, the system is to a certain extend based on the state of the art industrial robot technique, which is, due to its performance and reliability, well reputed in various industrial applications. Nukem is enhancing and adapting this technology to cope with severe nuclear environment and the particular challenges of nuclear decommissioning.

At present, the design of the system focus primarily on it’s application in a decommissioning project of a nuclear reactor in France where the complete remote dismantling operations of the reactor core components have been awarded to Nukem. Thus, the actual concept reflects the particular local situation: dismantling tasks, geometry, dimensions, etc..

Two dismantling systems are running one after the other on straight track sections which are also used for the guiding of the cable drag chains. Operational distance for long travel (between away parking position of the systems in the “home base” outside the reactor block and most far working position inside the reactor block) is approx. 25 -30 meters.

3. Applicability to Fukushima site, Technical challenges

Due to the multi-purpose concept the system is principally adaptable to carry out various other tasks and to work in other geometrical environment. The existing mobile robot design and its “tool-box” solutions (add-ons like cutting tools, grabs, monitoring equipment, etc.) may partly be taken 1:1 or will need only small modifications to meet at least several requirements at Fukushima site, e.g:

- Progressive forward penetration into damaged areas with severe radiological conditions which are inaccessible to operators, this includes cutting and removal of perturbing objects
- Gathering of visual information via video camera system
- Detection of local parameters via instruments and sensors
- Sampling of material
- Collection of fuel debris (via grab or vacuuming)
- Decontamination (wipes, vacuuming)
- etc. .

Various other appliances which are not yet covered by the extend of the actual design are highly imaginable and may be implemented without difficulties, e.g.:.

- Provision of a water-jet or foam spray system (e.g. for decontamination purposes)
- Concrete surface processing (decontamination)
- Concrete crushing
- Liquid collecting/removal system (e.g. via suction line)
- Drying system (e.g. via heated air stream)
- etc.

Special Application: Combination of the system with other special robots/systems

After removal of obstacles and laying the track, it is in principle possible to use the system also as “carrier system” which may transport and place (and at the end of operation also collect) other special remote operating robots, tools and other devices for particular purposes at particular locations inside the irradiated and contaminated area.

Example:

The system could carry the described Nukem crawler (see separate application **“Remote Controlled Vehicle (Crawler) to analyse situation in hazardous environment”**) on a trailer to a particular point of the for operators inaccessible area. Energy and media supply as well as signal exchange for the crawler will be carried along with in the cable chain system of the long travel system (i.e. connection between “home base” and trailer).

At the target location the system will now unload the crawler and place it onto the ground. Now the crawler can be operated by its own being connected to the trailer by its own cable chain system. The relative small crawler may now penetrate into areas which are inaccessible to the robot system, e.g. small corners, under pipelines, in flooded areas, etc.

At the end of the crawler mission, the crawler will be guided back to the “carrier system” where it will be picked-up by the robot and re-loaded onto the transport trailer. Now the units can return back to the “home base”.

Of course, the described carrier function can be performed in principle also for other special robots, tools and devices available from other suppliers.

Nevertheless, depending on their nature all the a.m. “new” applications will need, more or less, particular R&D activities until their serviceability.

4. Technology Development (Example)

The techniques exemplarily mentioned above were developed/designed or nuclearisised (adapted to nucler environment an d its specific requirements) by NUKEM and special sub-suppliers due to the specific requirements of the specific needs.

Possible developments with regards to the long travel system:

In the present design, the complete dismantling system is running on straight track sections which are also used for the guiding of the cable drag chain. Operational distance for long travel (between parking position of the system outside the reactor block and most far away working position inside the reactor block) is approx. 25 -30 meters. A moderate straight prolongation of the reach would not cause any problems. Nevertheless, in case the system should have, in other applications, a considerable longer travel or should also be capable to install and negotiate curved track sections and/or turnout sections, this will have impact on the design:

- Dimensional limits with regard to energy supply/media supply/data exchange via cable drag chain, need to be investigated and the cable management system probably needs to be ameliorated.
- Solutions for cariage and energy drag chain to cope with curved sections and/or turnout sections need to be developed
- In case of curved track sections/turnout sections the control software of the overall positioning/motion control/automatic anti colission system needs to be adapted.

Possible developments with regards to the robot

Mechanical part:

To our opinion this is only a limited requirement. In a first attempt it will be sufficient to select with regards to size/reach and handling/carrying capacitiy a suitable robot out of the large range of commercially available standard types.

Electrical/Control part:

Nearly each development with regards to long travel system/add-ons to the robot hand will require a suitable adaption of the control system, i.e. programming of barrier limits, optimisation of motion-sequence, introduction of supplementary control elements and visualisation on the operators desk/MMI, etc.

Possible developments with regards to add-on tools and devices:

As already mentioned, system capabilities may be extended by various other apliances like:

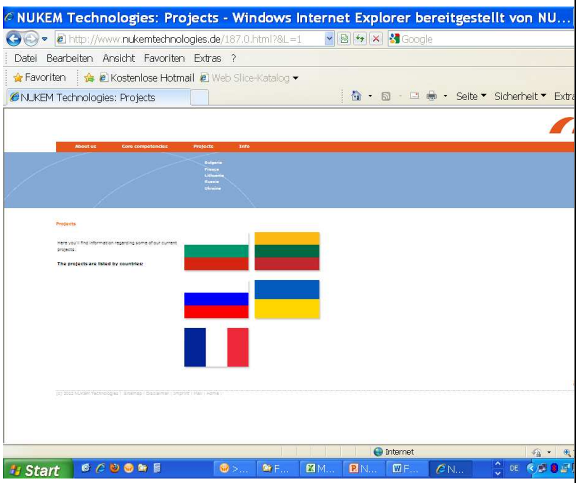
- Combination of the system with other robots/systems
- Provision of a water-jet or foam spray system (e.g. for decontamination purposes)
- Concrete surface processing (decontamination)
- Concrete crushing
- Liquid collecting/removal system (via suction line)
- Drying system (via heated air stream)
- etc.

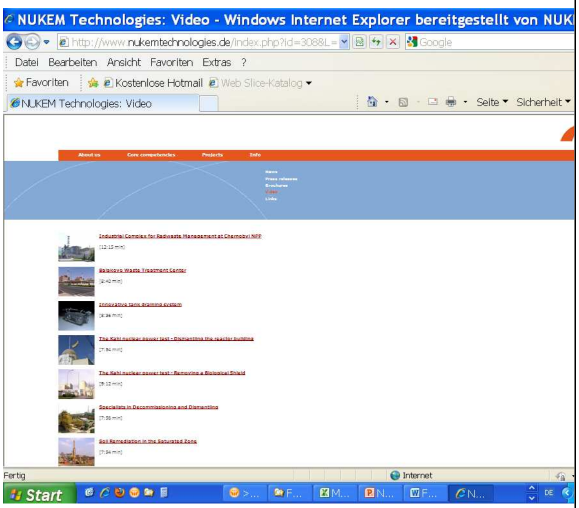
Limiting factors which have to be taken into account

- Implementation of supply/discharge lines into the cable management system
- Implementation of tools/devices to the robot hand/to the robot arms
- Stability of the complete system at maximum outreach of the robot under highest load applied to the robot hand
- Accessibility to the working area, e.g. dimensions of shielding door to be passed by the unit
- Dimensional restrictions within the working area

5. Note

Note





Reference documents:

- Company Presentation
- Projects

For further information please refer to

www.nukemtechnologies.de

Sublink ➡ Projects ➡ France

Sublink ➡ Info ➡ Video

"Innovative Tank Draining System"

http://www.nukemtechnologies.de/309.0.html?&L=1

Please refer also to separate application **"Remote Controlled Vehicle (Crawler) to analyse situation in hazardous environment"** send to you:

Title	Remote Controlled Vehicle (Crawler) to analyse situation in hazardous environment
Proposed by	NUKEM Technologies GmbH

The Crawler was designed and operated to remove

- crystallised salt,
- liquid RAW,
- sludge,
- IEX-resins

from collection tanks at Kola NPP (Russia).

Photo of Crawler

With its experience in the above mentioned dismantling project as well as in a big number of nuclear projects dealing with high irradiation and contaminated environment, not accessible for personnel, remote operation techniques required, requirement of tremendous decontamination behaviors before access possibility (operation of Waste Treatment Centers/Facilities and Decommissioning or Dismantling Projects) NUKEM has the qualification and is able to modify and adapt its remote operation techniques due to the specific needs (operational and economical) at Fukushima site.

Please refer to www.nukemtechnologies.de for further information and overview of NUKEM´s experience, competence and competition. Don´t hesitate to contact us in case of further questions or further information.

[Format 2-2] Session2: Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	
Title	**Automatic Path Planning for dismantlement**
Proposed by	**Kineo C.A.M.**

1. Technical description (Advantage, Specification, Performance)

Kineo C.A.M. is a software editor specialized in high-end automatic path planning software. The company provides a software environment to develop autonomous robotic motion planner. The technology can automatically compute and control the execution of any collision free motion for any mobile and articulated system.

Kineo Path Planning is made of several software components:

1. **KineoWorks, core library embedding the path planning algorithms**
2. **Kite Development Studio: 3D simulation environment used to simulate the environment and to develop dedicated path planning solution. It allows the best preparation of the actual operations by simulation to validate the feasibility of a removal of equipment's, accessibility paths inside cluttered environments.**
3. **Middleware integration (with ROS or RTMiddleware) to embed the technology on board of the robot.**

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

- **Computer Aided Robotics software like ROBCAD (Siemens PLM) or DELMIA (Dassault Systemes)**
- **AIST Japanese Intelligent Robot project**
- **Robaucoop project founded by the French Army: semi-autonomous EOD-UGV**
- **EDF power plant equipment simulation removal**
- **CANDU 6 reactors maintenance**
- **ITER project: simulation of removals of equipment's**

3. Applicability to Fukushima site, Technical challenges

1) **Lightweight UGV (Unmanned Ground Vehicle) are used to explore unknown contaminated area. Thanks to automatic path planning technology, the operator can indicate to the robot where to go or what to do (grasping an object, opening a door) and the robot automatically perform the task. It simplifies the task and increases the productivity of the UGV usage**.
2) **Simulation to prepare the operational tasks of removal and accessibility scenarios**

4. Technology Development (Example) - **AIST Japanese Intelligent Robot project** - **Robaucoop project founded by the French Army: semi-autonomous EOD-UGV** - **EDF power plant equipment simulation removal**
5. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Remotely operated vehicle for monitoring
Title	Remote controlled monitoring
Proposed by	AMEC

1. Technical description (Advantage, Specification, Performance)

Different design of remote controlled vehicles for monitoring (visual, radiation fields, sampling) of different part of NPP (rooms, tanks etc.)

Typical ROV consist from carriage body, rotation camera system with lighting and laser positioning system, swabbed contamination system collection system, monitoring of superstructure to measure dose rate at different height and remote control system.

ROV is easily adjustable depending on functional requirements and client´s needs. Basic functions include:

- monitoring of physical conditions (video recording)
- monitoring of the radiation situation (dose rates measurements
- sampling of non-fixed contamination
- general sampling of radioactive materials, retrieval and identification of small items.




2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)
   - Multiple applications on decommissioning projects at NPP A-1 in Jaslovske Bohunice

(Slovakia) - Belgoprocess Eurochemic reprocessing plant – monitoring - Trawsfynydd NPP, Wales, UK
4. Applicability to Fukushima site, Technical challenges - Monitoring of radiation situation of rooms with high radiation fields, surrounding monitoring of technologies, inspection of pipelines with diameter larger than 250 mm.
5. Technology Development (Example) - Technology developed / adapted for bespoke application
6. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

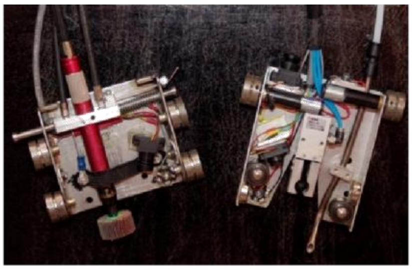
Technical Catalogue	
Mobile device classification	Remote Operated Vehicle
Title	Climbing ROV for inspection & remote installation of sensors
Proposed by	AMEC

1. Technical description (Advantage, Specification, Performance)

Climbing ROVs developed specifically to access narrow annular gap around cylindrical plant installation on nuclear power station to inspect the area and remotely install ultrasonic probes to monitor material thickness ongoing.

The ROVs were required to locate suitable mounting points, clean away debris and surface adherents (including paint) and then install ET probes using industrial adhesive.

Equipment was developed and techniques for use evaluated and perfected in short timescale so that ET probes could be installed at the next outage, total project duration being only 5 weeks.



2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Many years experience of various remote inspection and intervention projects on nuclear plant (and others), mostly in the UK.

3. Applicability to Fukushima site, Technical challenges
   - Access to confined areas for inspection
   - Deployment and remote installation of inspection devices

4. Technology Development (Example)
   - Technology developed / adapted for bespoke application

5. Note

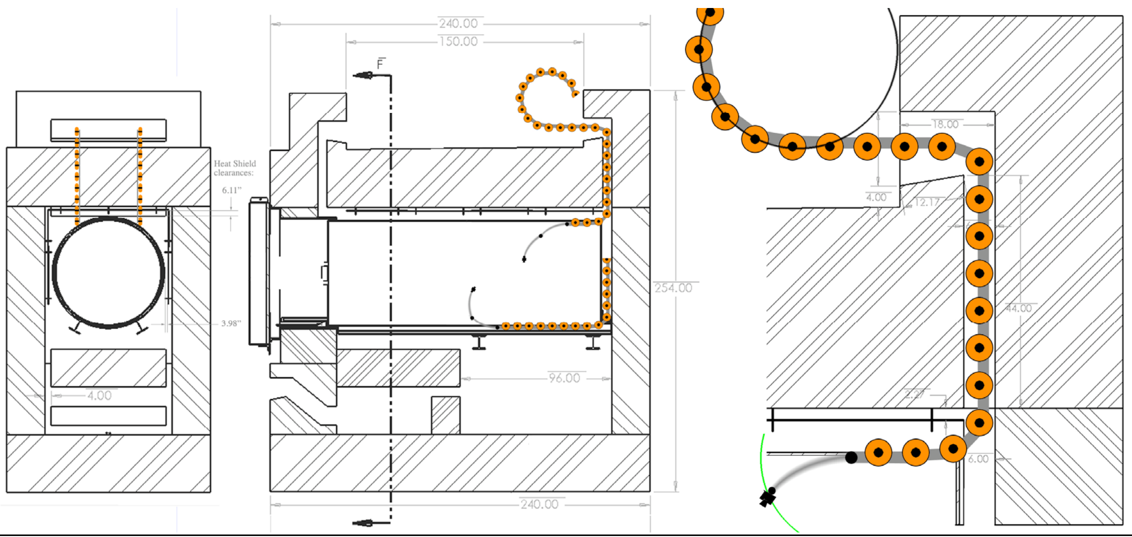
[Format 2-3] Session2

Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Traveling Mechanism (including Working Device)
Title	Dry Storage Inspection Device
Proposed by	Carnegie Mellon University Biorobotics Lab

1. Technical description (Advantage, Specification, Performance)

The Dry Storage Inspection Device is originally designed to inspect fuel rod dry storage containers in high radiation environments inside a dry storage container. The figure depicts a purely mechanical (except motors) double chain like vehicle that can be fed through the air vent, and guided to ride along the top of the stainless steel cylinder from rear to front to inspect the entire (approximately) 15 foot accessible length. Arms attached at each front side can be swung out to position cameras and other sensors closely about the upper half of the cylinder. Ideally these may be able to be designed to extend further down the sides of the cylinder for more coverage. Such a design could be adopted for missions at the Fukushima Daiichi Nuclear Power Plant for a specific mission, particularly reaching from the remote device access area through the PCV and into the suppression chambers. The only electronics on the double chain part if the vehicle are DC motors, which are powered by electronics on the spooling mechanism, making a system which can handle the radiation levels inside of the PCV. It is also possible to make the dry storage inspection device work underwater, using variable buoyancy to aid in locomotion. The device is deployed from a large spool enabling deployment by either remote control device or human operators.



2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

None.

3. Applicability to Fukushima site, Technical challenges

Applicable Issue	Applicability	Remarks and reasons (quantitatively)
Usability under a radioactive environment	YES	Everything on-board the mechanism, including motors, is radiation-hard by design.
Usability in a high temperature environment (60°C)	YES	High temperature rated components
Access to inside of pedestal	YES	Able to travel on inside of PCV using obstacles to aid in locomotion and support. No other snake-like or borescope robot can reach more than 5 meters; ours can go a much greater length
Application to narrow spaces	YES	Outer diameter is customizable.
Investigation of position/status of fuel debris	YES	Customizable to include camera and other sensors.
Correspondence to the disclosure of technical information/remodeling	YES	Customization according to intended purpose is possible.
Dispatch of operation engineers	YES	Dispatch to Fukushima Daiichi Nuclear Power Station is possible.

4. Technology Development (Example)

Device is currently a design concept, it is necessary to build and test prototypes before delivery to Fukushima Daiichi.

5. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

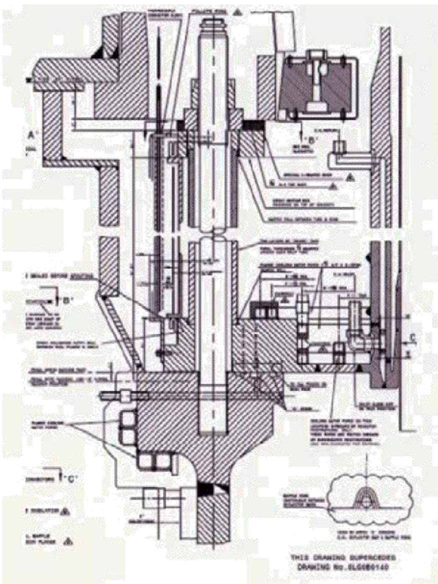
Technical Catalogue	
Mobile device classification	Remote Operated Equipment/Tools
Title	Remotely operated tools for remote cleanup, inspection and 3D mapping of inaccessible region on nuclear reactor plant.
Proposed by	AMEC

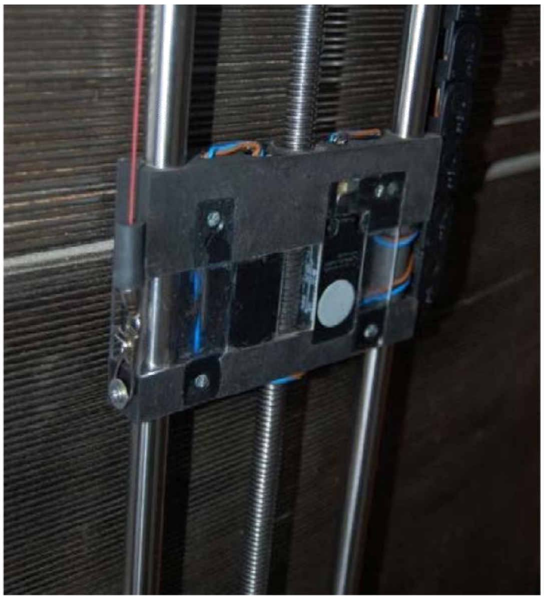
1. Technical description (Advantage, Specification, Performance)

Remotely operated long reach tooling developed specifically to access narrow vertical annular gap within cylindrical plant installation on nuclear power station. Tasks to be carried out remotely were:

- Remove loose insulating powder.
- Remove crust formed where insulating powder has soaked up/into grease covering on pre-stress wires.
- Clean off remaining grease from pre-stress wires.
- 100% CCTV inspection of pre-stress wire bundle.
- 100% Eddy Current mapping of pre-stress wire bundle and remaining space within annular gap.

Equipment was developed and techniques for use evaluated and perfected with all urgency as the problem had necessitated shutdown of four units, causing large loss of revenue. Multiple equipment packages were manufactured and a training facility was quickly set up and approx 250 additional staff hired and trained in the use of the new equipment. Deployed staff and equipment to the two power stations affected to carry out work as quickly as possible and return all four units to service.





2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.) Many years experience of various remote inspection and intervention projects on nuclear plant (and others), mostly in the UK.
3. Applicability to Fukushima site, Technical challenges - Remote access and remote operations applications
4. Technology Development (Example) - Technology developed / adapted for bespoke application
5. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Remote Operated Equipment/Tools
Title	Remotely operated tools for remote detection, cutting and welding in an inaccessible region on nuclear reactor plant.
Proposed by	AMEC

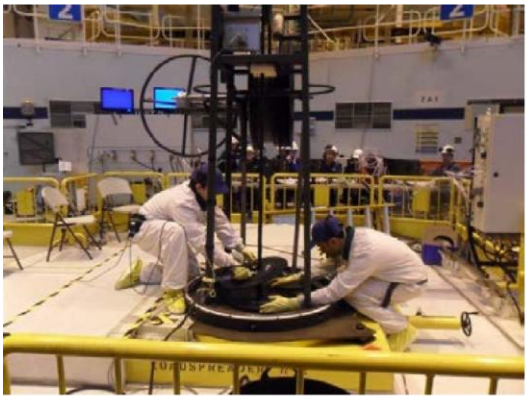
1. Technical description (Advantage, Specification, Performance)

Remotely operated tooling developed specifically to access control rod channels (approx 100 mm internal diameter) in nuclear power station. Tasks to be carried out remotely were:

- Detect presence of required plant features (not visible from channel – used magnetic detection system).
- Drill holes, drill counter-bores and create weld-prep.
- Weld plugs into first holes drilled (required only for access to drill holes further out).

Equipment was developed and techniques for use evaluated and perfected with all urgency as the problem, which affected four units, had necessitated some reduced power operation, causing loss of revenue.

Multiple equipment packages were manufactured and a training facility was quickly set up to prove equipment and qualify staff. Deployed staff and equipment to the two power stations affected to carry out work as quickly as possible and restore all four units to full power.



2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Many years experience of various remote inspection and intervention projects on nuclear plant (and others), mostly in the UK.

3. Applicability to Fukushima site, Technical challenges

- Remote operations such as detection, cutting and welding in inaccessible locations on nuclear reactor plant

4. Technology Development (Example)

- Technology developed / adapted for bespoke application

5. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Remote Operated Vehicle
Title	ROV for emergency remote inspection and evaluation of damaged power plant.
Proposed by	AMEC

1. Technical description (Advantage, Specification, Performance)

Pre-existing AMEC high-mobility remotely operated vehicle (ROV) adapted and equipment for task to access and inspect fire-damaged plant at power station. The fire damaged plant was destroyed internally, but the building remained standing, and internal inspection was required before demolition.

The inside of the plant was an unstructured environment with severe mechanical and chemical hazards. The ROV was required to navigate around the environment, to carry out hi-resolution video survey of the inside of the plant, and then return to deployment point for recovery.

ROV was adapted and refitted for use in this task in very short timescale so that remote inspection could be achieved as soon as possible. ROV was delivered to site and deployed into the fire-damaged plant less than 10 days after initial phone call.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Many years experience of various remote inspection and intervention projects on nuclear plant (and others), mostly in the UK.

3. Applicability to Fukushima site, Technical challenges

- Ability to carry out hi-resolution surveys (video) in “unstructured” and cluttered environments

4. Technology Development (Example)

- Technology developed / adapted for bespoke application

5. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Remote Operated Equipment/Tools
Title	Remotely operated tools for underwater remote survey and cutting in an inaccessible region on nuclear fuel reprocessing plant.
Proposed by	AMEC

1. Technical description (Advantage, Specification, Performance)

Remotely operated underwater tooling developed specifically to enter non-man-accessible vessel (approx. 200 mm internal diameter) in nuclear fuel reprocessing plant.
Tasks to be carried out remotely, underwater, were to detect presence of relevant plant features and cut holes in required locations.
Two equipment packages were manufactured and a training facility was set up to prove equipment and qualify staff. Equipment proven and staff qualified for task, presently awaiting instruction from client to deploy to site for implementation.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)
Many years experience of various remote inspection and intervention projects on nuclear plant (and others), mostly in the UK.

3. Applicability to Fukushima site, Technical challenges
    - Access to non-man-accessible vessels for remote surveying and cutting operations

4. Technology Development (Example)
    - Technology developed / adapted for bespoke application

5. Note

[Format 2-3] Session2　Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Remote Operated Vehicle
Title	ROV for emergency remote inspection and evaluation of part-constructed power plant.
Proposed by	AMEC

1. Technical description (Advantage, Specification, Performance)

Small, high-mobility remotely operated vehicle (ROV) specifically developed for remote inspection within steam header complex on part-constructed power station. Evidence had been found of debris within the headers, remote inspection was required to minimise cutting out of headers for debris retrieval.

Access to some headers was only possible through 90 degree 3 inch stub pipe, headers were various sizes from 12 inch to 24 inch. ROV was required to deploy through 3 inch stub, turn within the tube and then navigate around header complex to carry out inspection, then return to deployment point for recovery.

ROV was developed in very short timescale so that remote inspection could be achieved as soon as possible. ROV was delivered to site and deployed into the headers less than 2 weeks after initial phone call.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Many years experience of various remote inspection and intervention projects on nuclear plant (and others), mostly in the UK.

3. Applicability to Fukushima site, Technical challenges

- Agile remote inspection in various size pipework and headers

4. Technology Development (Example)

- Technology developed / adapted for bespoke application

5. Note

[Format 2-2] Session1: Remote-control decontamination

Technical Catalogue	
Mobile device classification	Sensor and tool delivery
Title	Intelligent Delivery Platform
Proposed by	Idaho National Laboratory

1. Technical description (Advantage, Specification, Performance)

Robotic platform has ability to operate over a broad range of autonomy level including teleoperation to full autonomous navigation. The software architecture used to control the robot is designed for easy integration of any sensor or tool. The Robot operating system fully integrates tool functionality, behaviors associate with tool operation, and navigation constraints placed upon the platform due to tool placement and operation. This platform could be used for sensor deployment, decontamination tool placement and operation, leak sealant application, general surveying including radiological and visual, and deployment of acoustic devices for leak detection operations. The platform measures approximately 1m X .5m X 1m. It has self contained power and includes wireless data transmission capability.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Days following the Fukushima events, the Idaho National Laboratory shipped an Intelligent Robotic Platform equipped with radiation detection capability to the reactor site. It was and is used extensively to map radiation field surrounding the reactors.

3. Applicability to Fukushima site, Technical challenges

Applicable to delivery of monitoring devices and tooling (decontamination, leak sealant, etc.) in and around the reactor vessel.

4. Technology Development (Example)

Integration of any tooling or monitoring devise identified for use. This is a low risk short term (less than a week) effort.

5. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Sealant
Title	Testing and use of Geosealants to stop leakage from Primary Containment Vessels
Proposed by	Idaho National Laboratory

1. Technical description (Advantage, Specification, Performance)

A critical problem in the refueling of Fukushima Daiichi Units 1-3 is the need for water for radiation shielding above the damaged fuel. Adequate shielding will require that the reactor cavity be filled to approximately the normal water level of the Spent Fuel Pools, ~ 30 m about the apparent present water level in the Drywell. Presently, water injected into the Reactor Pressure Vessel is leaking through the bottom of the RPV into the DW and thence somewhere out of the Primary Containment Vessel. The location of the leakage out of the PCV is unknown. Leakage may be occurring through the PCV itself, through failure locations in the Downcomers into the toroidal Suppression Chamber or from the SC itself. Leakage rates are ~1-3 m^3/hr.

A number of sealing techniques have been developed by the oil and natural gas industry in conjunction with hydraulic fracturing ("hydrofracking") technologies. These geosealants are used to contain and direct fluids through geological formations thousands of meters below the surface, at temperatures similar to those in the damaged reactors, though without the radiation fields. Exposure of the geosealants to gamma radiation will cause cross linking and may improve their sealing capabilities

The Idaho National Laboratory has the capability to test materials at high gamma fields surrounding spent fuel in the ATR Canal.

2. Applicability to Fukushima site, Technical challenges

Geosealants would stop the leakage of water out of the PCV and could provide a way the adequately shield operators during the defueling of the damaged reactors 1-3.

3. Technology Development (Example)

The formulation of the sealants may have to be altered to allow use in high gamma fields and so that cross-linking of polymers occurs at the appropriate time and location.

4. Note

CASE STUDIES

1.0 Hot Particle Removal

A small piece of activated satellite with a contact radiation field of 0.45MRads/h became lodged in the drain line of the steam generator primary bowl preventing area access and inspection. As the attached information shows Kinectrics not only customized but also operated the robotic crawlers with appropriate end effectors to remove the hot particle. Similar crawlers can be used to remove fuel debris and highly active components or deliver equipment to inaccessible areas of the Fukushima units.

2.0 Feeder Internal Delivery System

This is a small robotic device custom designed to deliver various inspection and maintenance payloads to difficult to access areas or the containment vessel.

3.0 Moderator Relief Duct Inspection Equipment (MORDIE)

This robotic inspection tool is equipped with Eddy Current and Ultrasonic Phased Array technologies, designed for inspecting large diameter piping.

4.0 Inspection Tooling

Technical information is provided in the attachments on a number of inspection techniques that when coupled with the robotic technologies can provide essential condition assessment information on component and vessel status at Fukushima.

5.0 Decontamination

5.1 Chemical Decontamination

Kinectrics has conducted a number of full system decontamination campaigns since 1981 based on the CANDECON ^{tm} process. The process utilized dilute chemicals that could be regenerated on ion exchange resins. Dilute processes reduced corrosion of pressure boundary materials and resulted in a reduced generation of radioactive waste requiring disposal but providing decontamination factors (radiation fields before/radiation fields after decontamination) in the 5-10 range. Although this process will not solubilize fuel debris, it will dissolve metal oxide films that adsorb fission and activation products from fuel failures.

5.2 Mechanical Decontamination

Fuel debris is highly insoluble and its removal requires physical/mechanical removal. There are a number of mechanical processes available on the market but Kinectrics has been developing a technique based on inducing the formation of cavitation bubbles in water flowing on the inside of a pipe using ultrasonic transducers strapped to the outside of the pipe. The cavitation results in a scouring action and the break up of solids to smaller sizes assisting in their transport to a filter or other mechanical device. The robotics described in previous sections could be utilized to deliver the ultrasonic transducers to the appropriate locations and deploy them remotely.

5.3 Advanced Dose Estimating Planning Tool (ADEPT)

The Advanced Dose Exposure Planning Tool (ADEPT^{TM}) is PC based software that provides 3D virtual reality job simulations for radioactive environments around reactor components. ADEPT^{TM} allows users to walk through a virtual job plan, while receiving a live estimate of the dose for simulated workers.

The worker dose estimation is based on a predetermined radiation field around the component and a user-defined job description. Radiation fields are based on measured historical data. This tool would be a very valuable asset to the radiation protection team at Fukushima to help them plan the recovery operations and rehearse the most effective approach to the recovery.

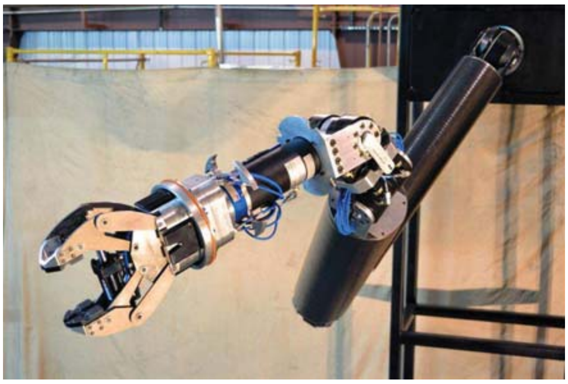
[Format 2-3] Session 2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Manipulators
Title	Carbon Fiber Long Reach Manipulators
Proposed by	S.A.Technology

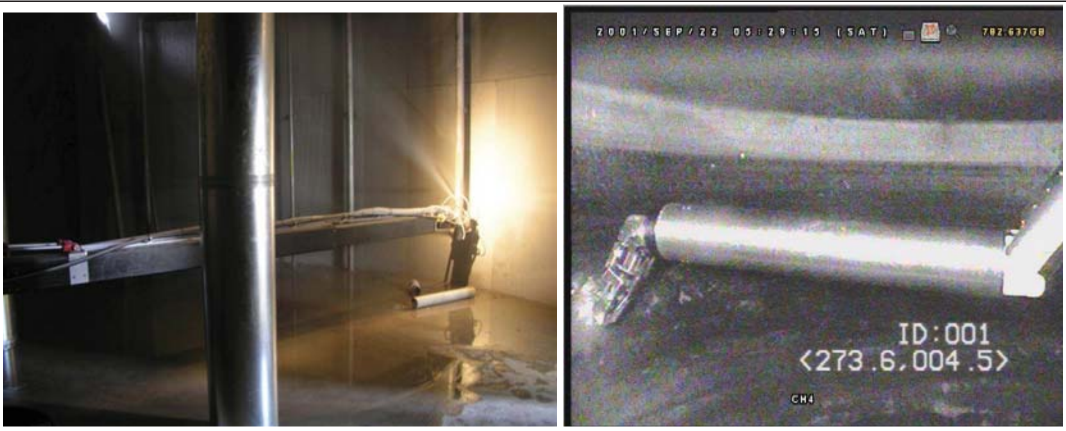
1. Technical description (Advantage, Specification, Performance)

Over the past decade, SAT has been utilizing carbon fiber composite materials to create manipulators for the nuclear industry that enable lighter, stronger, thinner, and stiffer manipulators to be deployed. Many nuclear projects require entry into confined radiological spaces through small penetrations. Carbon fiber is the ideal material for these applications because its stiffness to weight ratio is up to 18 times more than any metal. This allows longer reaches, through smaller penetrations, and with higher payloads.

Carbon fiber is an engineered material that can be optimized to the application. For most of SAT's projects we used fiber wound structural shapes such as square and round tubes.

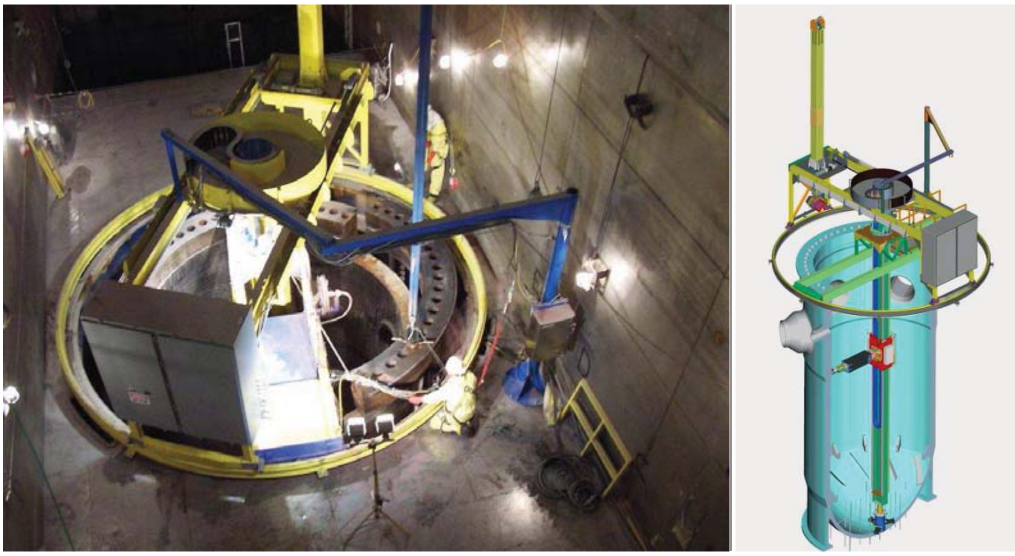


SAT has used carbon fiber manipulators in a wide variety of nuclear environments including reactor decommissioning, hot-cells, liquid waste tanks, and congested out-door facilities. The deployment options are project specific but can be done from horizontal penetrations (i.e. hot-cells), vertical penetrations (i.e. tanks), and mobile platforms (i.e. cranes and ROVs).



Examples of Carbon Fiber Manipulators in Waste Tanks

Examples of Carbon Fiber Arms in Hot Cells



Example of Carbon Fiber Arm in Reactor Decommissioning

Specifics such as reach, diameter, degree-of-freedom, and payload are very project specific but a few examples are listed below for reference:

1. Hanford Demonstration Arm
    a. Reach = 11.5m Horizontal / 10m Vertical
    b. Penetration Size = 300mm
    c. Payload = 150kg
    d. DOF = 4

2. Trawsfynydd RDA Arm
    a. Reach = 4m Horizontal / 4.5m Vertical
    b. Penetration Size = 225mm
    c. Payload = 45kg
    d. DOF = 7

3. Powered Remote Manipulator
    e. Reach = 3.5 Horizontal
    f. Penetration Size = 250mm
    g. Payload = 50kg
    h. DOF = 7

One other important characteristic of carbon fiber in nuclear environments is radiation tolerance. Carbon fiber is rated to approximately 100,000 Sv total dose (e.g. 100,000 hours in a 1 Sv/hr field) before any structural degradation of the material occurs.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

SAT has many years of experience deploying carbon fiber manipulators in nuclear environments including the following limited selection of projects:

1. West Valley Hot Cell Arms

2. K-Basin Fuel Pool Hydrolasing and Waterjet Arms

3. SMUD Reactor Cutup

4. Sellafield SIXEP Cutting Arm

5. Trawsfynydd RDA Arms

3. Applicability to Fukushima site, Technical challenges Carbon fiber manipulators are ideal to access hard to reach areas in high radiation environments. There are many areas related to Fukushima which will need such equipment. The flexibility of joints and mounting make it a good choice for a variety of operations and applications using the same manipulator system.
4. Technology Development (Example) No further technology develop is required. However project specific modification may be necessary.
5. Note

[Format 2-1] Session1: Decontamination

Proposal 1

Decontamination Technology Catalogue		Category No.		Page
Title	**Technology for applying dust suppressing coating with confinement effect**		Proposed by	**OOO Firma «Radez-2» Alexandrov NITI**

Applicable contamination condition			**Experience in remote-control condition**		
Form	**Solid**	Location	**YES**	**Using spray equipment including high-pressure sprayers**	
Adhesion	**Soft**	Floor/Wall/ceiling			
Penetration	Shallow	Machine surface	Reaction	**Yes** ( )	
Nuclide	Gamma / β α	Inside			

Principle: **Dust suppression coatings are applied on road sides, soil covering, sand pits, waste areas, and other dust-raising surfaces.** **Technology for applying dust suppression coatings with confinement effect is intended to reduce or stop desorption of radionuclides from dust-arising surfaces to the environment; to significantly decrease radioactive dust dispersal by wind effects etc.**	Collection method **Mechanical removal (if necessary)** Secondary waste form **Solid radwaste** Necessary utility **Preparation and delivery of compositions** Basic machine structure **Tanks and vessels, decon trucks, transportation tanks, fire trucks, helicopters etc.**
Principle Explanation: **Adhesion of radionuclides onto particles to form conglomerates resistant to wind erosion**	Safety measures/cautions **Normal safety precautions to observe when working with chemicals**
Past experiences/Decontamination effectiveness(DF): **Application in the 30 km radius zone of the Chernobyl NPP / Site decontamination with this technology reduced airborne activity in the atmosphere by 60 times as of September 1986.**	Decontamination capability/Performance speed **High** Size/Weight **Depending on performance demands** Applicability to Fukushima site/Technical challenges **Ready for use**
Note	Reference documents

Proposal 2

<table>
<tr><td colspan="2">Decontamination Technology Catalogue</td><td>Category No.</td><td></td><td>Page</td><td colspan="2"></td></tr>
<tr><td>Title</td><td colspan="2">Technology for decontamination («dry» decontamination), isolation and confinement of contaminated surfaces (soil, rooms, equipment, rolled roofing) using polymer coatings</td><td>Proposed by</td><td colspan="3">OOO Firma «Radez-2»
Alexandrov NITI</td></tr>
<tr><td colspan="3">Applicable contamination condition</td><td colspan="4">Experience in remote-control condition</td></tr>
<tr><td>Form</td><td>Solid</td><td>Location</td><td rowspan="2">YES</td><td colspan="3" rowspan="2">Using manipulators and sprayers</td></tr>
<tr><td>Adhesion</td><td>Soft</td><td>Floor/Wall/ceiling</td></tr>
<tr><td>Penetration</td><td>Shallow</td><td>Machine surface</td><td rowspan="2">Reaction</td><td rowspan="2">Yes
(   )</td><td colspan="2" rowspan="2">No</td></tr>
<tr><td>Nuclide</td><td>Gamma / α β</td><td>Accessible equipment surfaces</td></tr>
<tr><td colspan="3" rowspan="4">Principle: Decontamination, isolation, and confinement liquids are applied on contaminated surfaces, left to set until they harden, and then removed. The technology reduces or eliminates contamination and significantly limits radioactivity dispersal.
PVA- or PVB- based coating is used on room and equipment surfaces; PVAC- or polyvinylacetatel-based coating is used on rolled roofing.</td><td colspan="4">Collection method: mechanical removal</td></tr>
<tr><td colspan="4">Secondary waste form
Solid radwaste</td></tr>
<tr><td colspan="4">Necessary utility
Preparation and delivery of compositions</td></tr>
<tr><td colspan="4">Basic machine structure
Tanks and vessels, sprayers, etc.</td></tr>
<tr><td colspan="3">Principle Explanation: radionuclides are trapped by a polymer matrix which is then removed from a surface.</td><td colspan="4">Safety measures/cautions
Normal safety precautions to observe when working with chemicals</td></tr>
<tr><td colspan="3" rowspan="3">Past experiences/Decontamination effectiveness(DF):
Application in the 30 km radius zone of the Chernobyl NPP, at other NPPs (hot cells), nuclear fuel industries and research centers (e.g. Kurchatov Institute, VNIIHT) / Application of the technology reduces surface contamination to background level (decontamination factor is 40-1000 for one decontamination cycle).</td><td colspan="4">Decontamination capability/Performance speed
high</td></tr>
<tr><td colspan="4">Size/Weight
Depending on performance demands</td></tr>
<tr><td colspan="4">Applicability to Fukushima site/Technical challenges
Ready for use</td></tr>
<tr><td colspan="3">Note</td><td colspan="4">Reference documents</td></tr>
</table>

Proposal 3

Decontamination Technology Catalogue		Category No.		Page	
Title	**Complex technology for decontamination of residential houses, offices, neighboring territories and private lands**		Proposed by	**OOO Firma «Radez-2» Alexandrov NITI**	
Applicable contamination condition			**Experience in remote-control condition**		
Form	**Solid**	Location	**NO in respect of the complex of activities**	**Certain operations**	
Adhesion	Soft / Hard	**Floor/Wall/ceiling**			
Penetration	Shallow / Deep	**Soil and building surfaces**	Reaction	**Yes** ( )	No
Nuclide	**Gamma /** β α	**Accessible surfaces**			
Principle: 1) Mechanical removal of contaminated soil layers and other, disposal and recovery; **2) Treatment of walls, windows, roofs with washing solutions, concentration of contaminants in near surface soil layers, and mechanical removal. Treatment of cleaned surfaces with special solutions to prevent recontamination (water repellent treatment).** **3) Dust suppression or decontamination liquid coatings are applied to surfaces, left to set until they harden, and removed in the solidified form.** **The technology reduces or eliminates contamination and significantly limits radioactivity dispersal.**			Collection method: **mechanical removal** Secondary waste form **Solid radwaste** Necessary utility **Motor transport (bulldozers, decon trucks, transportation tanks, fire trucks), Equipment for preparation and delivery of compositions** Basic machine structure **Motor transport, tanks and vessels, sprayers, etc.**		
Principle Explanation: **contaminated substances are mechanically removed from surfaces; radionuclides are trapped by a polymer matrix which is then removed from a surface.**			Safety measures/cautions **Normal safety precautions to observe when working with motor transport vehicles, water solutions, and chemicals**		
Past experiences/Decontamination effectiveness(DF): **Residential and non-residential areas affected by the Chernobyl accident (Bryansk and Kaluga regions of Russia), buildings and territories in Pripyat (the Ukraine). Complex treatment reduces surface contamination to background levels.**			Decontamination capability/Performance speed **Medium or high** Size/Weight **Depending on performance demands** Applicability to Fukushima site/Technical challenges **Ready for use**		
Note			Reference documents		

Proposal 4

Decontamination Technology Catalogue		Category No.		Page	
Title	**Complex technology for decontamination of construction machinery and transport vehicles**		Proposed by	**OOO Firma «Radez-2» Alexandrov NITI**	

Applicable contamination condition			**Experience in remote-control condition**		
Form	**Liquid / Solid**	Location	**NO in respect of the complex of activities**	**Certain operations**	
Adhesion	**Soft**	**Machine surfaces**			
Penetration	**Shallow / Deep**	**Surfaces**	Reaction	**Yes** ( )	No
Nuclide	**Gamma / β α**	**Accessible surfaces**			

Principle: 1) Mechanical removal of contaminated soil layers and other, their disposal; **2) Treatment of surfaces using high-pressure equipment, such as Karcher high-pressure washers and steam jets. Collection and treatment of water.** **3) Removal of contaminated paint coatings by washing with solvents.** **4) Decontamination polymer liquids are applied to surfaces, left to set until they harden, and removed.** **The technology reduces or eliminates radionuclide contamination.**	Collection method: **mechanical removal** Secondary waste form **Solid radwaste, LRW** Necessary utility **Decontamination stations, mechanical and liquid (chemical) decontamination equipment, equipment for preparation and delivery of chemical compositions** Basic machine structure **Motor transport, tanks and vessels, sprayers, etc.**
Principle Explanation: **contaminated substances are mechanically removed from surfaces, contaminants are removed by using washing solutions and together with paint coating, radionuclides are trapped by a polymer matrix which is then stripped from a surface.**	Safety measures/cautions **safety precautions to observe when working with high-pressure equipment, motor transport vehicles, water solutions, and chemicals**
Past experiences/Decontamination effectiveness(DF): **Decontamination of construction machinery and vehicles (more than 2500 machines) involved in remedial activities after the Chernobyl accident.** **For example, decontamination of the “Демаг-СС-400” № 16” crane which had been operated in Chernobyl Unit 4 rooms since July 1986 led to a decrease in exposure rate from 10 r/h to background level, surface contamination – from $5 \cdot 10^4$ Bq/cm^2 to < 1 Bq/cm^2 (beta); other cranes: surface contamination – from 10^5 Bq/cm^2 to < 1 Bq/cm^2 (beta) and exposure rate from 0.5 r/h to 0.8 r/h.** **A large amount of decontamination work was done on**	Decontamination capability/Performance speed **Medium or high** Size/Weight **Depending on performance demands** Applicability to Fukushima site/Technical challenges **Ready for use**

various motor cars and their engines, as well as helicopters.	
Note	Reference documents

[Format 2-2] Session1: Remote-control decontamination

Proposal 1

Technical Catalogue	
Mobile device classification	**Device for remote decontamination of contaminated surfaces**
Title	**Adhesive web for remote decontamination**
Proposed by	**OOO «Firma «Radez-2», Moscow** **Alexandrov Research Institute of Technology (NITI), Sosnovy Bor, Leningrad region**
1. Technical description (Advantage, Specification, Performance) **The proposed decontamination technology is based on using specially designed devices, so-called "adhesive webs". The "adhesive web" is a web-shaped structure coated with adhesive material. The web size and weight-lifting capability, as well as adhesive composition depend on specific job demands. Adhesive webs were used to remove both fine-dispersed contamination (radioactive dust, crushed fuel and fuel rod pieces, etc.) and contaminated equipment parts of up to 1.5 t weight (fragments of fuel assemblies, structural and graphite bricks, etc.) which were thrown out onto roofs during the Chernobyl accident.** **The adhesive web technology is an "unmanned" approach to decontamination. This approach significantly reduces exposure of personnel and thus improves working conditions for both radiation emergency workers and those who participate in decommissioning operations.** **The adhesive web technology used for decontamination of surfaces does not produce liquid radioactive waste. As to solid wastes, they can be conditioned and compacted to reduce their volume by 1.5-2.**	
2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.) **The decontamination technology based on "adhesive webs" was widely used to clean roofs and land in the first phase of Chernobyl post-accident activities in 1986.**	
3. Applicability to Fukushima site, Technical challenges **The technology is ready for use at Fukushima site. No technical challenges are faced.**	
4. Technology Development (Example) **The technology can be used for remote removal of contaminated equipment, including components with fuel inside, and concrete structures from the plant site and damaged reactor rooms at Fukushima NPP.**	
5. Note	

Proposal 2

Technical Catalogue	
Mobile device classification	**Quick setting polymer composition**
Title	**Technology for deactivation of contaminated items using quick setting polymer compositions**
Proposed by	**OOO «Firma «Radez-2», Moscow** **Alexandrov Research Institute of Technology (NITI), Sosnovy Bor, Leningrad region**
6. Technical description (Advantage, Specification, Performance) **Under post-accident conditions, there may be required to temporarily stabilize radiation-hazardous items or securely isolate contaminated buildings and equipment for prevention of radioactivity dispersal and further damage to engineering structures.** **The technology for deactivation of contaminated items using quick setting polymer compositions mainly consists in remotely applying special-purpose compounds to nuclear- or radiation-hazardous items. The proposed compound is fire-, radiation-, heat, and acid/alkali solution resistant and efficiently sorbs radionuclides. With this technology, the composition locally fills voids, gaps, apertures and other hard to access places, thus, reducing the area of contaminated surface-atmosphere contact and, consequently, radioactivity dispersal.**	
7. Past experience (Plant in Japan, overseas plant, application in other industries, etc.) **A similar technology was used to isolate the surfaces of fuel-containing debris and structures in the Chernobyl Shelter.**	
8. Applicability to Fukushima site, Technical challenges **The technology is ready for use at Fukushima site. No technical challenges are faced.**	
9. Technology Development (Example) **The polymer composition can be used for isolation/deactivation of damaged nuclear fuel during its transport and storage.**	
10. Note	

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	**Device for remote measurement of ambient gamma dose rate**
Title	**Festoon system for dose measurements**
Proposed by	**OOO «Firma «Radez-2», Moscow** **Alexandrov Research Institute of Technology (NITI), Sosnovy Bor, Leningrad region**
1. Technical description (Advantage, Specification, Performance) **The festoon system for dose measurements consists of a cord made of anti-adsorption material (nylon, PVC, PU, etc.) and gamma-ray dosimeters (e.g. pellets with dirt-protective coating) attached along the cord length at intervals (e.g. 0.25-1.0 m) which are specified depending on monitoring requirements. The cord with dosimeters is transported to the monitoring area by a crane of manipulator and fixed in local geometry. After specified exposure time the dosimeters are removed and doses are measured. The measured gamma ray dose and exposure time are used to assess the dose rate and determine the gamma ray field in the control area. The cord with dosimeters can be fixed at a metal (aluminum or steel) tube for better rigidity (to prevent swinging of the structure).**	
2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.) **Similar festoon systems were used for dose rate measurements and reconstruction of gamma ray fields in the area of fuel-containing debris and structures in the Chernobyl**	

Shelter (damaged reactor hall, under reactor space, walls, roofs, etc.)
3. Applicability to Fukushima site, Technical challenges **The technology is ready for use at Fukushima site. No technical challenges are faced.**
4. Technology Development (Example)
5. Note

Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Calandria Inspection Tool (CVIT) and Debris Removal Tool (DRT)
Title	Calandria Vessel Inspections and Debris Removal
Proposed by	Candu Energy Inc.

1. Technical description (Advantage, Specification, Performance)

CVIT & DRT System

The Calandria Inspection Tool (CVIT) was developed to perform inspections of the inside of the reactor vessel via an operator on the tooling platform located outboard of the reactor face. The CVIT tool consists of two RAD tolerant cameras, 1 colour with zoom capability, and 1 black and white.

Initial inspections performed found debris located inside of the Calandria requiring the development of a Debris Removal Tool (DRT). Figure **1** shows the CVIT and DRT on their respective work tables located outboard of the reactor face.

Both tools are approximately 20 feet long and have articulating and telescoping arms. These tools can cover a 360 ° rotation and 100° arm flexion and are controlled by manual operations from operators located on the reactor platforms. Figure **2** shows both tools located inside of the calandria vessel. The DRT has interchangeable scoops with the ability to pick up large items such as swab cloths, and the dexterity to pick up small items such as wires.

Vacuum System

The vacuum tooling was developed to remove smaller debris from the calandria vessel. The vacuum tooling consists of a process system (vacuum motor, waste container, and hoses), as well as a Calandria Vacuum tool (Cvac), and vision system that are both inserted into the calandria through lattice sites. Similar to CVIT and DRT the vacuum tool is approximately 20 feet long and have articulating and telescoping arms. These tools can cover a 180 ° rotation and 100° arm flexion and are controlled by manual operations from operators located on the reactor platforms. The process system equipment is adapted from the CANDUclean equipment used successfully for steam generator cleaning applications. Figure **3** provides an overview of the vacuuming process.

The Calandria Vessel Vacuum Tooling is designed to remove small debris from the reactor vessel via fuel channel lattice sites (Figure **4**). The small debris consists of: short metallic wires (< 1.5” in length), small metallic and/or non-metallic chips (swarf), iron-oxide red dust, carbon ion exchange resin and other particles. The tool was manually operated from the outboard end on the reactor face similar to the CVIT and DRT and designed to manoeuvre around the reactivity control mechanisms inside the calandria. All components of the Cvac were designed to withstand 10.4 MRADs.

Waste Management System

The waste container is used to contain accumulated debris from the vacuum system and provides shielding, including up to 1 kg of spent fuel (concentrated or dispersed). Figure **5** shows further details of the waste container design. There are two cyclone separators internal to the waste container with excellent efficiency. After using these waste containers for the Bruce Power Units 1 and 2 debris removal campaigns, there was only a light dusting of the HEPA filters downstream of the waste container, proving the efficiency of the cyclone separator design.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Calandria Inspections (CVIT):
- 2009 - Bruce Power, Units 1 and 2

Debris Removal (DRT):
- 2010 - Bruce Power Units 1 and 2
- 2010 - Pt. Lepreau

Debris Removal (Cvac):
- 2010 - Bruce Power Units 1 and 2
- 2010 – Wolsong
- 2011 – Pt. Lepreau

Other:

Candu Energy Inc. (Candu) is a leading full-service nuclear technology company providing nuclear power reactors, services and nuclear products to customers worldwide. Our 1,400 highly skilled employees design and deliver state-of-the-art CANDU® reactors, and carry out reactor life extension projects, provide plant life management programs and tools (including automated robotic tooling), and offer operation and maintenance services for existing nuclear power stations.

Current Major Projects underway include:

- Life Extension of the Bruce Nuclear Generating Station
- Life Extension of the Point Lepreau Nuclear Generating Station
- Life Extension of the Embalse Nuclear Generating station
- Life Extension of the Darlington Nuclear Generating station
- Development of Enhanced CANDU 6 Reactor Technology
- Pre-project engineering and planning for Cernavoda units 3&4 new build

As the former CANDU reactor division of AECL, Candu Energy has a high degree of expertise and experience in the nuclear industry. Our Tooling & Services division specializes in the design, development and operation of specialized robotic tooling used for reactor core inspections, reactor maintenance, and reactor life extension projects. In particular, our major life extension projects utilize a suite of remotely controlled automated robots to perform safe removal of highly radioactive reactor components from the reactor core.

Technical Catalogue	
Mobile device classification	Remote inspection and repair tooling
Title	Life extension program - National Research Universal (NRU) reactor
Proposed by	Candu Energy Inc.

The life extension program of the National Research Universal (NRU) reactor is another example of remote inspection and repair. This reactor has been in operation since 1957 and is still operating well beyond its intended design life. NRU is used as a neutron source for materials research and CANDU reactor materials development; it also plays a major international role in the manufacture of medical isotopes for diagnosis and treatment of 20 million patients a year world-wide.

Corrosion of the aluminum reactor vessel has thinned the wall and caused perforation in several areas and the vessel wall has corroded in a few places from the outside. The nearest human access was 30 ft above the repair site with access through a 4.75 inch diameter hole, also repair of irradiated aluminum made this repair a complete challenge.

It was recognized early in the program that a variety of remote tools would be required to execute such a complex repair.

One of the main tooling that was designed and manufactured for this repair was a complex remote welding tool to apply weld deposit on the inner surface. For the areas of perforation, an aluminum patching plates was used.
The challenge of delivering the weld from a height of 30ft and through a small hole was considerable. See figure 1.

A mock-up was constructed to replicate the height and access restrictions. A delivery tool/robot was designed in the form of a vertical mast to be inserted vertically into the reactor. The lower end of the mast housed an arm that could be folded out horizontally to reach the surface of the vessel.
Within the mast and arm are all the controls necessary to remotely operate a weld tool mounted on the distal end of the horizontal arm. To stabilize the mast/arm assembly, the lower end of the mast engaged an existing socket device on the floor of the reactor. See Figure 2

Tool Delivery System
The main structure of the delivery system is a tube that houses a guide rail and a vertical travel assembly. The travel assembly drives the tool into the reactor via a motor/chain mechanism. A high ratio gear motor and optical encoder provides accurate weld control and positional feed-back.
To control the rotational position, a steering assembly is mounted on the operator deck plate. A gear motor and a programmable optical encoder provide rotational motion and positional feedback.

Weld Head
The weld build-up head assembly incorporates axial and circumferential motion to deploy the head from the delivery system and provide motion for welding. Also the wire feed and welding video cameras are mounted on the assembly. A scissor mechanism moves the head out of the delivery tube and presents the weld torch to the repair site. The scissor drive also serves as the AVC axis. A manual drive is also provided for fail-safe back up. Video feed-back was considered essential and the torch assembly includes leading and lagging cameras to view the weld pool.

Grinding System
In the event of weld defect, such as porosity etc, it may be necessary to grind out the defect.
A grinding system is delivered similar to the weld-head and is deployed radially on the AVC axis. The grinding system uses a two bar linkage driven by a micro motor and a small cylinder. Grinding feed is along the delivery system ‘Z’ axis.
Incorporated into the head is a vacuum system which surrounds the grinding burr to recover chips and prevent contamination in the reactor. A camera assembly is located above the grinder to monitor operation. The camera’s tungsten housing retains the lens, spot filter and leaded window.
The grinding assembly is configured with a horizontally mounted grinding tool. Actuation is in the radial direction using the AVC motor. The grinder approaches the reactor wall in the clockwise direction to allow for stable grinding and minimize chatter. See figure 3.

1. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

This project took place at AECL Chalk River from November 2009 until June 2010.

2. Applicability to Fukushima site, Technical challenges

Candu has experience developing tooling and inspection capability for unique reactors and unique environments. The physical damage at the Fukushima sight means that it is a unique environment.

3. Technology Development (Example)

This equipment was developed specifically for the NRU project.

4. Note

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Current Major Projects underway include:

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- Development of Enhanced CANDU 6 Reactor Technology
- Pre-project engineering and planning for Cernavoda units 3&4 new build

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Session 2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Inspection Sampling Tool
Title	Vessel Inspection Tool
Proposed by	Candu Energy Inc.

1. Technical description (Advantage, Specification, Performance)

A radiation tolerant camera system used to inspect components and retrieve debris or samples from inside a nuclear reactor core. This tool is designed to be delivered over 20 feet through a 5” diameter opening into the vessel.

See photos in format 3

Inspection is performed using a radiation tolerant camera capable of receiving up to 100MRad total dose. The camera includes on-board lighting and allows pan/tilt/zoom capabilities to allow viewing at any angle.

The camera delivery system folds onto itself to reduce its total length during delivery. It offers 4 degrees of motion and is remotely controlled using radiation tolerant electric motors and pneumatics. A mechanical gripper or instrumentation/sensors can be installed at the end-effector for sampling or measurement applications.

This tool can be delivered horizontally over 20 feet to pass through shielding walls or to position the camera in optimal inspection locations. This distance can be customized based on the specific application.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Used to inspect CANDU nuclear reactor internal components during reactor refurbishment projects:

-Bruce Power A Units 1 and 2
-Point Lepreau
-Wolsong 1

3. Applicability to Fukushima site, Technical challenges

Suited for use to view internals of PCV. Delivery and setup of tool at the inspection location would need to be customized for the particular application.

4. Technology Development

This technology was developed suddenly to assist a customer with their emerging needs for containment vessel inspection. An important aspect of the development was a mutual understanding of the inspection criteria.

5. Note

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Candu

Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Liquid Injection Safety System (LISS) inspection tooling
Title	Calandria Tube to LISS Gap Measurement
Proposed by	Candu Energy Inc.

Technical description (Advantage, Specification, Performance)

Another Reactor Inspection tooling developed by Candu Energy includes the Calandria Tube to Liquid Injection Safety System (CT-LISS) inspection tool. This tool is used to measure proximities between the CT and LISS mechanisms. The Inspection Tool is approximately 50 feet in length when assembled as shown in Figure 1. The assembly is inserted into the top of the calandria vessel through the view port. The camera head shown in Figure 2 is attached to the bottom-most section and houses a radiation resistant camera and 2 banks of halogen lights. The camera is equipped for the radiation environment, having a dose tolerance of 2x108 R. A 90º mirror attachment allows the camera to be mounted parallel to the central axis of the inspection tool, and observe in a direction perpendicular to the central axis. The cables for the camera control, image signals, and supply of lighting are routed internally, through the tube sections to the top of the inspection tool, and from there to the Control and Data Acquisition System. An example inspection photograph of a LISS nozzle inside Bruce Unit 3 is included in Figure **3** below.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

CT-LISS Inspection:

- 2012 - Bruce Power, Unit 3
- 2011 - Embalse
- 2010 –Embalse
- 2010 - Bruce Power Unit 3
- 2009 - Bruce Power Unit 1
- 2009 –Bruce Power Unit 8
- 2008 –Bruce Power Unit 7
- 2008 –Pickering Unit 7

2007 - Bruce Power Unit 3
2007 –Bruce Power Unit 4
2007 –Bruce Power Unit 6
2006 –Wolsong Unit 1
2006 –Gentilly Unit 2
2005 –Bruce Power Unit 5
2004 –Point Lepreau
2003 –Gentilly Unit 2
2003 –Wolsong Unit 1

3. Applicability to Fukushima site, Technical challenges

This tool has been deployed to sites over the world and Candu could deploy this to Fukushima. The tool would have to be brought to the inspection site.

4. Technology Development

Candu has recently developed a secondary lighting feature for this tool that can provide additional lighting in the camera field of vision for higher quality inspection photographs.

5. Note

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Session 2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	
Title	Real-Time Video Processing Software: Filtering Radiation Noise from Remote Video-Aided Visual Inspections
Proposed by	Candu Energy Inc.

1. Technical description (Advantage, Specification, Performance)

Candu Energy Inc. (formerly known as Atomic Energy of Canada Ltd.) has gained valuable experience from its nuclear reactor vessel visual inspection programs. From its inspection programs Candu Energy has developed a technology of reducing the radiation noise from the video signal in real-time, as shown in the example images attached. The benefits of the technology are:

- Improve overall quality of the remote video-aided visual inspection by filtering radiation noise from video signal in real-time, or after recording.
- Provide immediate feedback to the inspection team, potentially reducing time on reactor by avoiding repeat inspections by real-time confirmation that the images are useful.
- Ability to identify hidden objects/indications with greater confidence (see Figure 1).
- Extend service life of cameras.

The real-time video processing software will filter the radiation noise from the colour camera on-site. Black and white video can be processed, but usually does not need it. The filtered colour camera video signal would provide better opportunities for TEPCO to identify potential problem areas at the time of the inspection.

Candu

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

This technology has been deployed and used at each of our major life extension projects:
-Bruce Power 'A' Units 1 and 2
-Point Lepreau Generating Station
-Wolsong 1

3. Applicability to Fukushima site, Technical challenges

The Fukushima inspection videos of the reactor building that have been observed have radiation noise similar to the images seen in Candu inspections before we started processing the images. Candu Energy has the software and hardware to assist in the recovery work at Fukushima.

4. Technology Development

5. Note

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[Format 2-3] Session2　Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	System Integration of Delivery Systems
Title	Design, Development, and Deployment of Remotely Controlled Equipment Delivery Systems
Proposed by	Idaho National Lablorotory

1.　Technical description (Advantage, Specification, Performance)

Inherent with access to and performing work in high radiation areas is the need for remote/robotic deployment of instruments and equipment for sensing, sampling, cleaning, dismantling, and various types of remote handling in the hazardous areas.　Industry has yet to provide comprehensive delivery platforms that can be successfully used inside these hazardous environments.　Integrated systems consisting of off-the-shelf, modified off-the-shelf, and/or R&D type developed equipment for these areas are required.

The INL has designed, developed, and tested large and small systems for the express purpose of working in these hazardous environment.　A few of these are as follows:

The TMI-2 Core Stratification Sampling System provided the international scientific community with 10 eight foot long stratified core samples of the TMI-2 reactor core.　This system was a complex integration of uniquely designed hardware and equipment coupled with off-the-shelf equipment and hardware.　Additionally, due to the uniqueness of the equipment, it was used for rubble bed pulverization, inspection of the lower head regions of the reactor vessel, and assisted in the dismantlement of the core support structure.

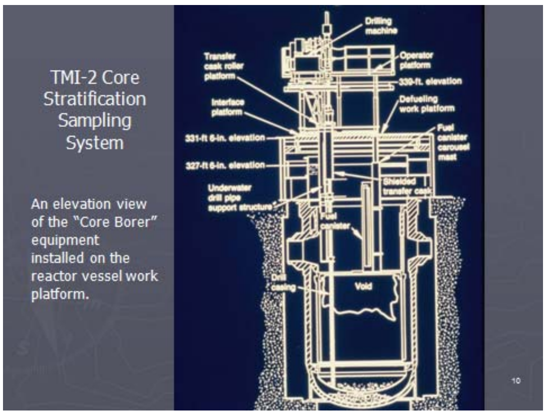


Figure 1 TMI-2 Core Stratification Sampling System

The Cooperative Telerobotic Retrieval System, a development under the Department of Energy Buried Waste Integrated Demonstration Program, provided for remote retrieval of buried waste. This technology was a large gantry robot and included 30-axes of computer controlled motion. Motions could be either tele-operated or robotically controlled. The control center was located in a remote location away from the equipment and included 2-D video cameras/monitors, 3-D camera pairs/monitors, and a real-time simulation graphical user interface associated with retrieval equipment components. The system employed three platforms mounted on a common bridge designed to cooperate with each other; two telescoping masts and a 5-ton hoist. Deployed from the masts were two 6-axis servo-hydraulic manipulators. Soil handling was performed by an integrated vacuum system and a conveyor system for soil deposition into containers.

Figure 2 Cooperative Telerobotic Retrieval System

The Yucca Mountain Waste Package Closure Project developed a prototype production system to remotely weld both inner and outer lids of 7 ft diameter x up to 20 ft long waste packages (vessel in a vessel) inside a hot cell environment. The system provided for all utilities, electronics, electrical, handling equipment, controls, safety systems to demonstrate this robotic material handling/weld cell. The cell consisted of a linear motor driven cart for moving materials into/out of the cell, two welding robots and a unique track system to deploy them on, an overhead gantry robot (RHS) for material handling and delivery/removal of specific weld characterization equipment. All material handling and weld process were robotically controlled, although teleoperation of equipment was available as well. The cart and RHS handled materials weighing up to 4000 pounds into and out of the cell including closure lids, waste package purge and backfill equipment, and weld stress mitigation equipment. The weld cell included a number of 2-D cameras that were strategically located throughout the cell area. A complete safety system was also incorporated, allowing several levels of interlock, dependent upon the mode of operation being performed. The completed demonstration provides for containment of stockpiled radioactive materials originally scheduled for storage at Yucca Mountain.

Figure 3 Yucca Mountain Waste Package Closure System

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

The examples cited were all designed, built, and tested at the INL. The TMI-2 Core Stratification Sampling System was successfully deployed at TMI and performed the actual work described.

3. Applicability to Fukushima site, Technical challenges

Remote access inside the Fukushima reactors requires complex equipment that has not been commercially developed for the environment extremes there. The examples cited demonstrate INL's ability to conceive, design, build, test, and deliver complex systems that will perform in these environments.

4. Technology Development (Example)

Systems for characterization of reactor cores (as in TMI); remote platforms for handling tools to provide access to critical subfloor areas for sensor and equipment deployment; remote platforms for handling debris and materials using 2-D/3-D technologies.

5. Note

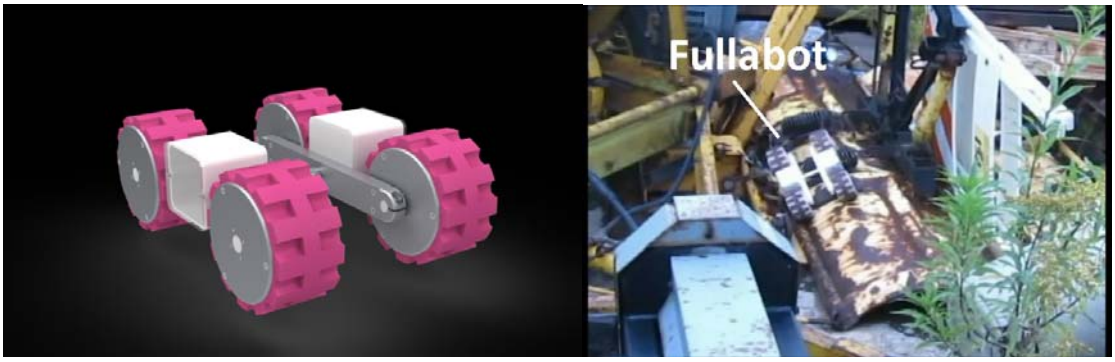
[Format 2-3] Session2

Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Traveling Mechanism (including Working Device)
Title	Fullabot
Proposed by	Carnegie Mellon University Biorobotics Lab

1. Technical description (Advantage, Specification, Performance)

Originally designed for archaeology research in caves in Egypt, Fullabot is a small, battery powered, versatile mobile robot able to self-travel over rough terrain. The main benefit of Fullabot is that it is light and small: it has the same form factor as a small portable computer or net-book. It is easy to deploy and can actually sit on top of other robots for longer-term transport. The current instantiation of the design is simply a minimalist H-frame chassis with battery motors located inside of the wheels. Further improvements will include the addition of the “fifth wheel,” a wheel mounted on a 1-DOF arm to provide additional traction on slopes, the ability to traverse rougher terrain or debris, and go upstairs, as well as “Baby-bot” a smaller mobile base which can be deployed from Fullabot to get in to areas so small that Fullabot cannot fit.



The figures show a CAD rendering of Fullabot as well as the current prototype taversing industrial equipment. Fullabot can be operated wirelessly as well as via fiber optic or copper tethers and will include a tether payout spool. Fullabot is water-resistant and with minimal changes could be made fully submergible in up to two meters of water. Due to its small size and weight Fullabot could easily be deployed from another mobile robot or by a single human operator. Weight: 1.8 kg; Dimensions: 18 cm width X 29 cm length X 10 cm height,

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Fullabot has been tested in search and rescue simulations.

3. Applicability to Fukushima site, Technical challenges

Applicable Issue	Applicability	Remarks and reasons (quantitatively)
Usability under a radioactive environment	Unknown	To be tested in radioactive environment, but many components are rad-hard
Usability in a high temperature environment (60°C)	YES	Rated to function in up to 80°C.
Underwater operation	YES	Operation possible at depths up to 2 meters;
Access to inside of pedestal	YES	Able to self-travel on floors as well as over and around rubble and debris. With fifth wheel, able to climb stairs.
Application to low clearance spaces	YES	Height is 10cm.
Investigation of position/status of fuel debris	YES	Contains camera.
Correspondence to the disclosure of technical information/remodeling	YES	Customization according to intended purpose is possible.
Dispatch of operation engineers	YES	Dispatch to Fukushima Daiichi Nuclear Power Station is possible.

4. Technology Development (Example)

Development to include additional sensors which may be useful in the desired environment.

Development is necessary to test radioactive compatibility and harden the device to radiation and improve operation in high temperature environments.

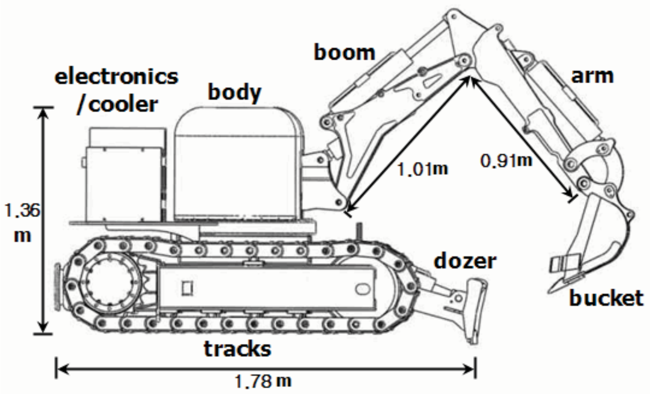
5. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Traveling mechanism and Working mechanism
Title	Autonomous Working Robot in Hazardous Environments
Proposed by	Korea Advanced Institute of Science and Technology and Korea Institute of Machinery and Materials, collaborating with Hydraumatics Co.,Ltd.

1. Technical description (Advantage, Specification, Performance)

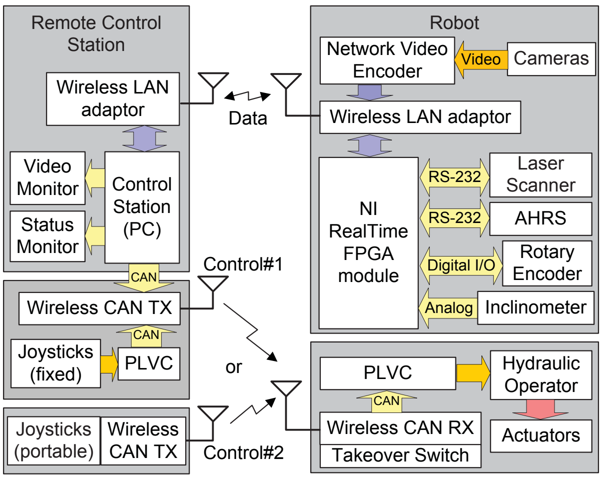
(1) A vehicle with two narrow tracks powered by hydraulic system enables the robot to move on uneven and rough surfaces. The mechanical specification is as listed in the table. This vehicle was originally developed for remote operation in underground coal mines in Korea. The vehicle is equipped with a shovel and a breaker, which make it ideal to perform excavation and demolition of structures. The vehicle is also designed to be explosion-proof in underground mines with methane.

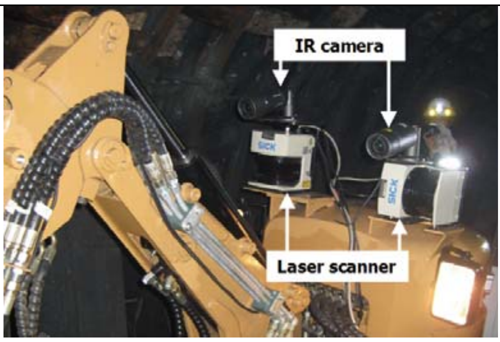


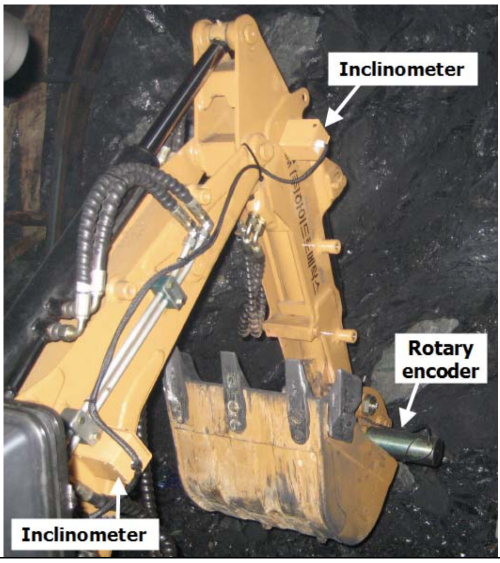
Dimension (Length/Width/Height)	1.78x0.75x1.36 [m]
Weight	2500 [kg]
Max. Driving Torque	300 [kgf.m]
Hydraulic Pressure	200 [bar]
Electric Motor Power	20 [HP]
Hydraulic Pump Capacity	45 [l/min]
Max. Velocity /Climbing Capability	1.2 km/h / 20 deg

(2) Performance capability: The vehicle is equipped with onboard inertial sensors, laser scanners for 3-D mapping of obstacles, indoor localization, waypoint-based autonomous driving. The vehicle is also equipped with multiple cameras with video transmitter. The vehicle can be operated manually and autonomously under the supervision of remote operators in real-time. The operator at a remote location can command the vehicle to perform tasks such as digging, rock breaking, and forward/back/turn motions. The vehicle is also programmed to perform simple “canned” tasks such as shoveling and breaking to ease the task of the remote operator. Also, the robot can be operated at a higher autonomy level to detect debris (in this case heaps with high levels of radiation) and move them to a designated location.

(3) Onboard sensors and remote control station : laser scanners, IR cameras, AHRS, rotary encoders, inclinometers to localize the robot and to build 3-D obstacle map. A 3-D mapping algorithm and a Monte Carlo Localization(MCL) algorithm using particle filter are implemented to localize the robot in GPS-denied environments. After localizing itself, the robot can move to waypoint following traversable path that avoiding obstacles. Measured data including stereo video by the onboard sensors are transmitted back to remote operator to enhance the operators' spatial perception.







2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

This robot was successfully field tested in the underground coal mine at Hwasoon, South Korea in Sep. 2011. The coal mine (400 meters under the sea level) has a very harsh working environment with high temperature (>30 degrees Celsius), high humidity (90~100%), noise, and dust.

3. Applicability to Fukushima site, Technical challenges

Applicable issue	Applicability	Remarks and reasons (quantitatively)
Usability under a radioactive environment	YES (with minor modification)	All components are enclosed to satisfy water-proof(IPx7), dust-proof(IP6x), and designed to aim for explosion-proof. A little modification is needed to use under a radioactive environment.
Correspondence to the disclosure of technical information and remodeling	YES	Correspondence to the disclosure of technical information and remodeling is possible.
Application to narrow corridors	YES	Robot width : 750mm

4. Technology Development (Example)

Power supply: the vehicle is currently powered by external electricity source, which turns the electric motor connected to the hydraulic pump. The vehicle can be also operated with stand-alone onboard powerpack, which consists of internal combustion engine connected to a generator (hybrid configuration). The engine can be directly connected to the hydraulic pump.

Autonomy: the vehicle is basically designed to operate by a remote operator, who monitors the robot's activity by wireless cameras. The vehicle's operation can be made more efficient by implementing autonomous behaviors specific to the needs at the powerplant.

Radiation protection: the vehicle should be examined for radiation condition as it was originally designed for underground mine operation. The vehicle is however tested for high temperature and high humidity conditions as well as high level of dusts.

These issues are further discussed in format 3.

5. Note

[Format 2] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Mobile Device for identifying Leak Areas in the PCV (R&D Road Map 2-(1)-2)
Title	Remote Detection and Visualization of Leakage using Microphone Array & CCD Camera
Proposed by	Jin-Ho Park

1. Technical description (Advantage, Specification, Performance)

- **Fundamental Principle**
  - A leakage from a structure (pressurized vessel and piping, etc.) generates acoustic leakage signal, which can be used for leak point detection. The leak position can be identified by using the microphone array system that equipped with a source localization algorithm.
  - In addition, the steam leak generates heat-haze around the leak location. This can be detected by applying an image processing technique to the obtained CCD camera image.
- **Overview**
  - The technique for detecting leakage of pressurized steam from a pressure vessel or piping system
  - The up-to-date real time monitoring system to localize the leakage just using a CCD camera and microphone array
- **Characteristics and Specification**
  - New image/signal processing for detecting leakage of steam
  - Equipped with advanced image/signal processing techniques
  - Equipped with user friendly GUI environment for quick and easy display
- **Patent**
  - Korean patent No. 1086142, 1044866
  - On applying patents to USA

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.):

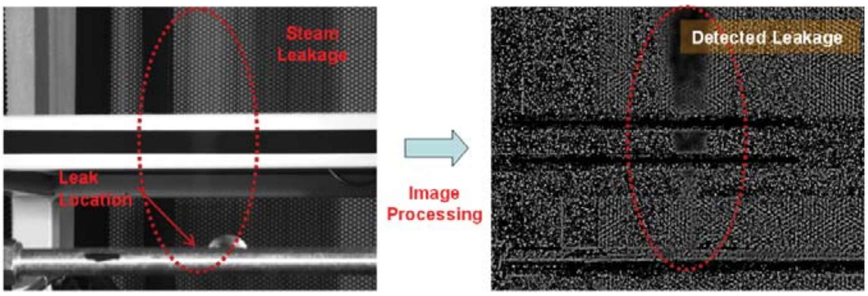
- The feasibility of the proposed method has been verified by performing an experiment in the laboratory of KAERI.

3. Applicability to Fukushima site, Technical challenges:

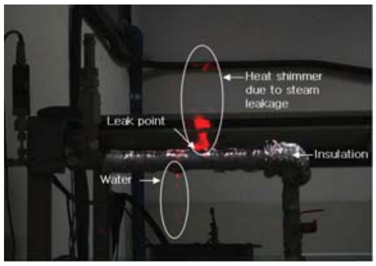
- Leak monitoring, real-time detection of leak location of the outer surface of PCV
- On-line visual leakage monitoring of pressurized components in power plant on a real-time basis

4. Technology Development (Example)

- **Steam Leak Detection using CCD Camera**
  - Available for detecting the invisible leakage from the high pressure boundary
  - Available for finding the leakage even from the hidden pipe inside insulation



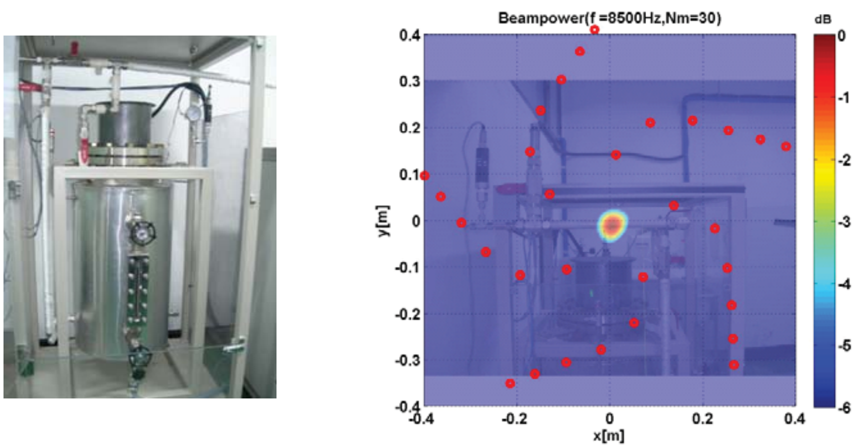
<Original Image of CCD Camera> <Image after applying proposed technique>



<Steam leak detection for insulated pipe>

Steam leak detection experiment by using CCD Camera

- **Leak Detection using Microphone Array**
  - Quick and easy detection & visualization of the leakage location



Leak detection experiment by using microphone array

5. Note

[Format 2] Session2 Remote-control operation machine and measurement equipment for CV inspection

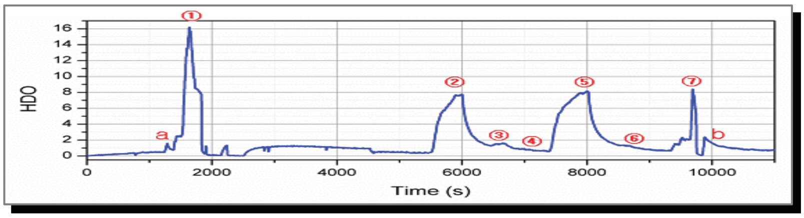
Technical Catalogue	
Mobile device classification	Mobile Device for identifying Leak Areas in the PCV (R&D Road Map 2-(1)-2)
Title	Remote Detection of Leak Location by Laser Humidity Sensing
Proposed by	Do-Young Jeong

1. Technical description (Advantage, Specification, Performance)

- **Laser humidity and semi-heavy(HDO) water detection for coolant leak detection of nuclear power plants**
  - Real-time and sensitive detection with wide dynamic range
  - Remote detection by using suction cables as long as 100m

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

- **Coolant Leak & Leak Location Detection in PHWR**
  - Leak detection of pressure tubes of Calandria of candu power plants
  - Leak location detection of valves and tubes of primary coolant system



3. Applicability to Fukushima site, Technical challenges
   - Coolant leak & leak location detection of PCV

4. Technology Development (Example)

5. Note

[Format 2] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Underwater Crawler
Title	Underwater Crawler module for inspection and debris removal
Proposed by	Kyoung-Min Jeong

1. Technical description (Advantage, Specification, Performance)
   - Dimension : 400mm (L) x 250mm (W) x 220mm (H)
   - Weight : 30 kg
   - Water proof : 20m depth
   - Maximum inclination : 40 deg
   - Maximum speed : 100mm/sec
   - One color CCD camera is mounted (can be tilted up and down)
   - Attaching tool: Suction, Intake
   - One Suction cup is mounted underside
   - Minimum diameter of opening for entrance : 300mm
   - Remote control distance up to 40m (extendable to 100m)
   - Radiation hardening (electronic parts): 1KGy TID

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)
   - Its performance was evaluated in a tank mockup in South Korea

3. Applicability to Fukushima site, Technical challenges
   - Debris removal and cleaning at the bottom of RV and PCV

4. Technology Development (Example)
   - Should be redesigned for requirements of remote operation in Fukushima NPPs

5. Note
   - Radiation hardening design concepts are implemented up to 1KGy TID

[Format 2] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Mobile Robot for Remote Operation
Title	On-Line Hybrid Electronic Radiation Dosimeter for Highly Radioactive Area
Proposed by	Nam-Ho Lee

1. Technical description (Advantage, Specification, Performance)

- **Hybrid Sensor for High radiation detection:**
  - Neutron Dosage with PIN Diode-type (~ 10kGy(Si))
  - Gamma/X-ray Dose with pMOSFET-type (~ 100kGy(Si))
  - Gamma/X-ray Dose rate with Si PN Diode (~ 100kGy(Si))

- **On-Line Radiation Monitor:**
  - Calculation and processing of the radiation signal from the radiation sensors
  - Real time monitoring and alarming of the high level irradiation
  - Data correction and confirmation with diversity concept

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

- Its performance was evaluated at the reactor area in Wolsong nuclear power plant (South Korea)

3. Applicability to Fukushima site, Technical challenges

- Radiation measuring for PCV internal and radiation detection in highly activated leaking area

4. Technology Development (Example)

- Should be modified in accordance with the environmental considerations and design changed for a proper adaptation in the Fukushima NPPs.

5. Note : To utilize for robotic dosimetry in high dose area

[Format 2] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Mobile Robot for Remote Operation
Title	Integrated Mobile Robotic System for Radiation Monitoring and Leakage Detection
Proposed by	Seungho Kim

1. Technical description (Advantage, Specification, Performance)

- **Integrated Monitoring Modules**
  - Leakage Detector using Microphone Array and CCD Camera
  - Highly Sensitive Laser Humidity Sensor with Wide Dynamic Range
  - Hybrid Electronic Radiation Dosimeter
  - Infrared Stereo Camera

- **Mobile Robotic System with Heavy Duty Elevation Mast**
  - Payloads up to 30kg
  - Accessible higher than 10m
  - Shape-shifting Crawler Mechanism with Omni-directional Wheel
  - Ditch Crossing larger than 0.7m
  - Remote control range longer than 100m

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

- The mobile Robotic system was dispatched to execute remote operation of the fuel handling machine in Wolsong NPPs

3. Applicability to Fukushima site, Technical challenges

- Radiation measuring and leakage detection outside of PCV Area

4. Technology Development (Example)

- The dimensions should be adjusted to permit to entrance into working areas in Fukushima NPPs and the monitoring modules may also be redesigned

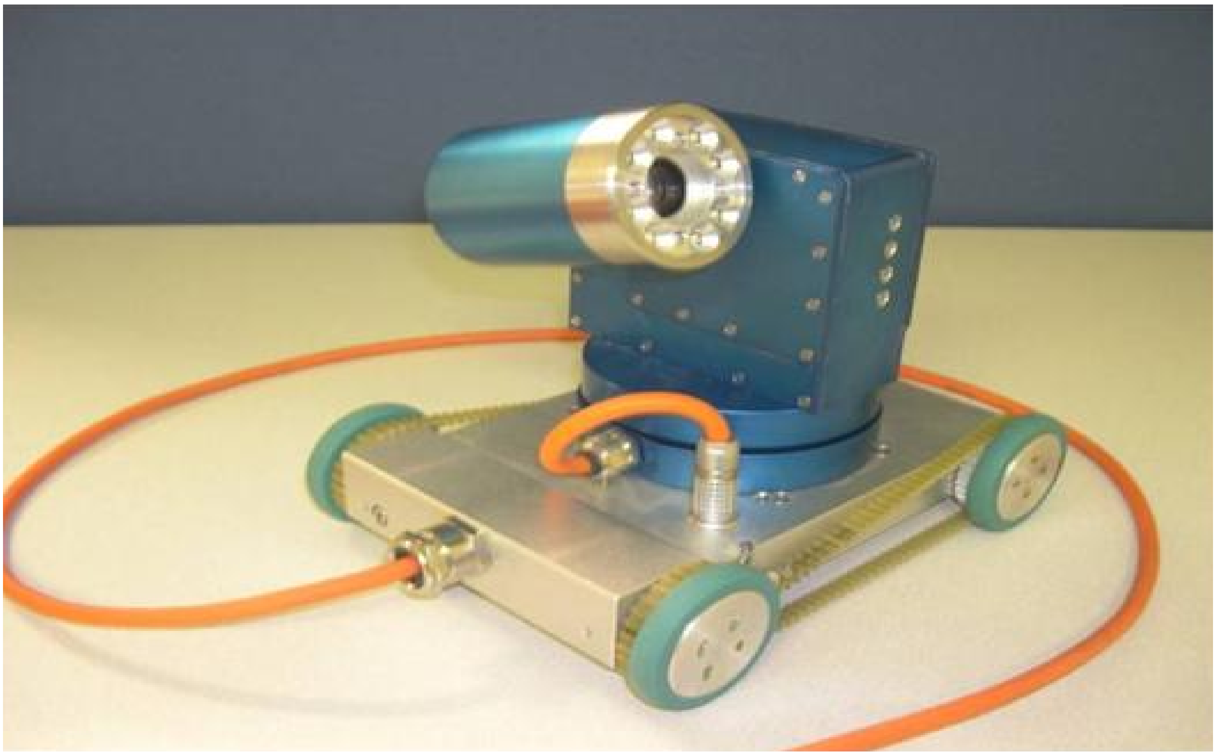
5. Note : Remote manipulators can be mounted to the top of mast

[Form 2-3] Session 2 (Technologies relating to mobile equipment and measuring instruments for remote operation of containment vessels, etc.)

Technical catalog	
Category of mobile equipment	Televisual Inspection
Title	CHATV Crawlers
Proposer	ONET TECHNOLOGIES

1. Technical details (Features, specifications, performance, etc.)

CHATV Crawlers : 6 remote-controlled crawlers for the BMI inspection of the reactor vessel



The load-bearing crawler can move according to two axes (forward/backward and right/left) and combine a rotation movement:

- Revolving turet
- CCD frame camera with zoom, manual and automatic focusing and with an annular lighting including 8 LEDS of 1W.

This CHATV crawler was developed in order to perform the following operations on the tank bottom penetrations and on the Socket Weldings:

- detection operation
- taking of complementary images (zoom, freeze frame)

These phases are performed by the same camera of axial type and zoom-equipped.
This camera is on a turret, enabling it to an unlimited revolve-turret movement of – 70 to 90°.
The whole turret-camera is itself on a 4-wheels crawler
At this level, it is inserted into the access plated opened beforehand.
This tool is remote-controlled thanks to a control unit linked to the crawler by only one umbilical cable, giving all the necessary information such as the crawler and the turret movements, the functioning of the camera, the lighting control and the images transfer.
This information is multiplexed. It enables us to have a 8mm-diameter umbilical cable. The mass of the former is reduced and its suppleness increased: the blocking risks are therefore highly reduced.

The length of the umbilical cable (30 m.) enables us to install the control unit in the regulated work area in the annular space.

The CHATV crawler, which technical information is detailed hereafter, is composed of a crawler load-bearing a turret-camera.

This crawler moves thanks to two engines located on each side of it. It has a double drive because it is a tracked crawler (front wheels linked to back wheels)
This design enables :

- the crawler to move, either on its wheels or thanks to it caterpillars. The wheels increase the capacity of crossing an obstacle,
- to have a four-wheels motricity
- a rotation on the spot of the crawler

To reach all penetrations, the crawler was conceived in order to be able to perform the following movements:

- move forward
- move backward
- rotation to the right
- rotation to the left

Technical information of the crawler

TECHNICAL INFORMATION	
LENGTH	260 mm
WIDTH	185 mm
REST CAMERA HEIGHT	250 mm
ON HEIGHT CAMERA HEIGHT	265 mm
MASS	9 kg
OPERATIONAL DISTANCE	50 m

Combining the revolving-turret movements, the turret enables us to steer the camera in all directions around the crawler. The revolving-turret movement
However, it is possible to automatically find the horizontal camera position and in the front of the crawler by maintaining the button rested during a few seconds.

The televisual inspection will be performed by this camera which technical capacities enable us to detect 3mm-diameter indications.

The camera

The chosen camera for the operation is a colour-CCD technology, zoom-equipped enabling us to obtain the wanted image frame whatever is the position of the camera on the insulation.
The regulating of the focusing can be made automatically (autofocus) or manually. This choice enables the pilot to adjust the image neatness on a very precise point during the taking of complementary images.
In this way, it is the electronic of the camera which manages an optimal signal for the reading of the image.
This camera is equipped with an annular lighting.

2. Track record (Including domestic plants, overseas plants, and in other industries)

French nuclear power plants

3. Grounds for and technical issues with regard to possible application to Fukushima Daiichi Nuclear Power

lant

System for remote-controlled televisual inspection in a irradiated environment

Application task	Possible or not	Notes: reasons etc. (quantitative)
Use in a radiation environment	Yes	Conçu pour cela
Use in a high-temperature (60ºC) environment	Yes	Conçu pour cela
Access to within pedestal	Yes	
Examination of position/state of fuel debris	Yes	
Adaptation to disclosure of technical information and improvement	Yes	
Dispatch of operating technicians	Yes	

4. Technologies to be developed (Examples)

5. Notes

[Form 2-3] Session 2 (Technologies relating to mobile equipment and measuring instruments for remote operation of containment vessels, etc.)

Technical catalog	
Category of mobile equipment	Televisual inspection
Title	Cameras
Proposer	ONET TECHNOLOGIES

1. Technical details (Features, specifications, performance, etc.)

Cameras : Severals inspection cameras for reactor vessel (CT 121, DTR 65, VS 340)

Camera CT 121

Camera DTR 65 HRC (F)

Camera VS 340 N very hard radiation tolerance with interchangeable lenses and light

Camera VS 340

VS 340 is a state-of-art bi-unit camera with very hard radiation tolerance.
Its lens and front window are made with non browning glass, which withstand the integral irradiation dose of $2x10^6$ Rad without decreasing their optical performance. The camera is perfectly suited for applications such as :

- Inspection of reactors interals
- Inspection of nuclear fuel
- Surveillance in confined areas
- Assistance to service operations in reactor vessel.

Caméra CT121

Revolving turet camera with 4 floodlights (260 W direct lignhting), with 30 m umbilical cable length.
Housing material : stainless steel (waterproof et decontaminable). Protection degree IP68. Overall dimension Lg. 373mm (without termination design) with 4 floodlights or lg 185mm with 2 floodlights

(installed each side). Weight : 8 Kg.
- Camera type CCD colour, horizontal resolution >460 lines TV, zoom 312x [26x optic, 54.2°, f=3.5mm (big view angle) à 2.2°, f=91mm (TV), et 12x numeric].

2. Track record (Including domestic plants, overseas plants, and in other industries)

Frend nuclear power plant

3. Grounds for and technical issues with regard to possible application to Fukushima Daiichi Nuclear Power Plant

Cameras for remote-controlled televisual inspection

Application task	Possible or not	Notes: reasons etc. (quantitative)
Use in a radiation environment	Yes	Made for that
Use in a high-temperature (60ºC) environment	Yes	Made for that
Access to within pedestal	Yes	
Examination of position/state of fuel debris	Yes	
Adaptation to disclosure of technical information and improvement	Yes	
Dispatch of operating technicians	Yes	

4. Technologies to be developed (Examples)

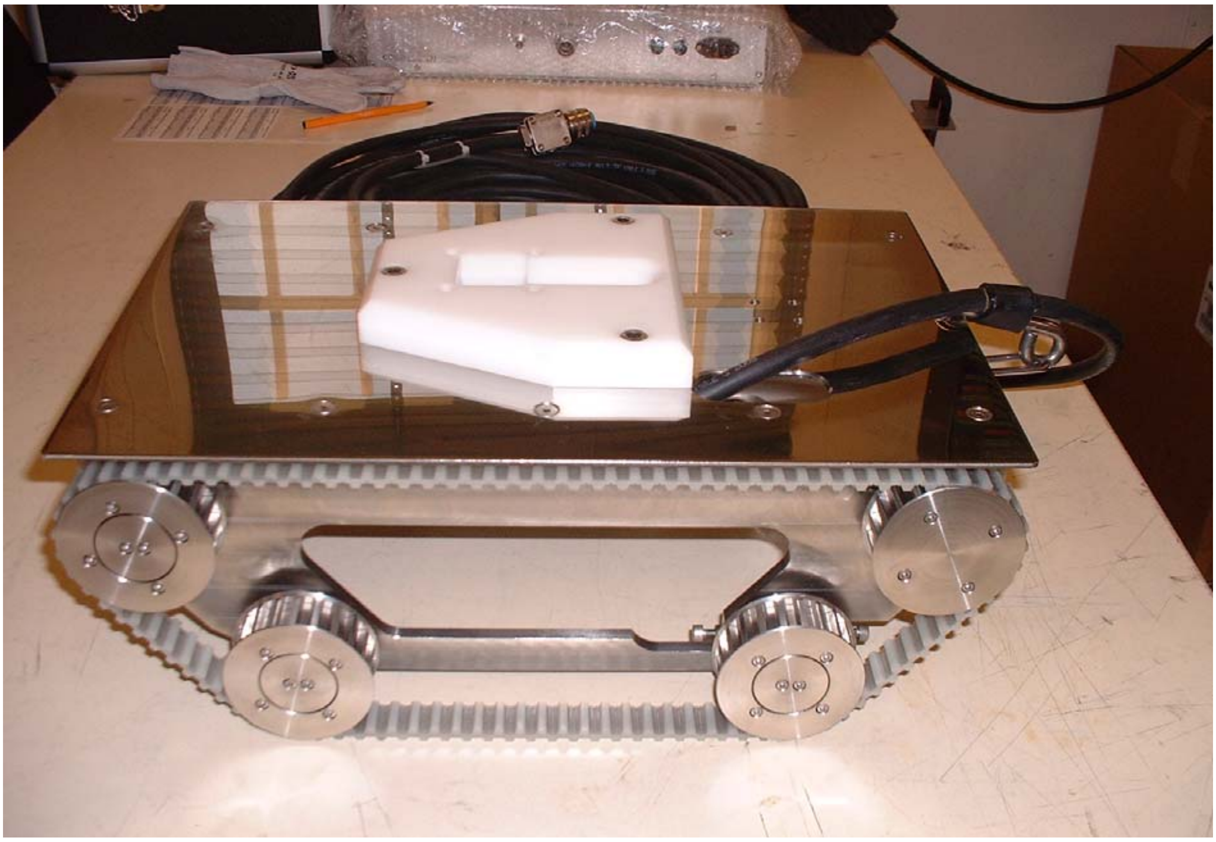
5. Notes

[Form 2-3] Session 2 (Technologies relating to mobile equipment and measuring instruments for remote operation of containment vessels, etc.)

Technical catalog	
Category of mobile equipment	Televisual inspection
Title	Remote controlled crawler ARIANE
Proposer	ONET TECHNOLOGIES

1. Technical details (Features, specifications, performance, etc.)

Remote controlled crawler ARIANE for televisual inspection for safety equipments



This crawler is equipped with two motorized and independent caterpillar train. These catterpillar are fixed by an horizontal base plate with a mounting hole:

- Cameras for televisual inspections
- Remote controlled arm for recovering loose part

Load capacity can reach 50 kg.
30 m umbilical cable length.

2. Track record (Including domestic plants, overseas plants, and in other industries)

Frend nuclear power plant

3. Grounds for and technical issues with regard to possible application to Fukushima Daiichi Nuclear Power Plant

Remote controlled crawler ARIANE for televisual inspection for contaminated area

Application task	Possible or not	Notes: reasons etc. (quantitative)
Use in a radiation environment	Yes	Conçu pour cela
Use in a high-temperature (60ºC) environment	Yes	Conçu pour cela
Access to within pedestal	Yes	
Examination of position/state of fuel debris	Yes	
Adaptation to disclosure of technical information and improvement	Yes	
Dispatch of operating technicians	Yes	

4. Technologies to be developed (Examples)

5. Notes

[Form 2-3] Session 2 (Technologies relating to mobile equipment and measuring instruments for remote operation of containment vessels, etc.)

Technical catalog	
Category of mobile equipment	Televisual inspection
Title	Robotic equipment NAJA III
Proposer	ONET TECHNOLOGIES

1. Technical details (Features, specifications, performance, etc.)

NAJA III : remote controlled equipment for Canopy seal televisual inspection on reactor vessel head

NAJA III equipment are developed for remote controlled operations of canopy weld on vessel head adapter. Its design suits for all types of vessel head (PWR 900 MW, 1300 MW and 1450 MW).

This equipment enable to make theses operations on Canopy seals :

- Detection operation by televisual examination
- Characterization operation by complementary images
- Mechanical cleaning operations

This equipment is made with one arm runing through vessel head adapter. It allows to control all welding canopy seal of each control rod drive mechanism adapter.

This Televisual-Examination control took is composed of:

- A head including a camera
- A lighting of variable intensity (16 Leds splited as follows : 4 groups of 4 leds independently controlled. The four groups are independent and enable us to realize nuances and drop shadows making it easy to analyze the defects.

2 control mode are available :

- one mode "detection " (field 24 x 32 mm) identifying 1mm side surface defect
- one mode "complementary image" (field 8 x 10,6 mm) allowing 5/100 mm analyse and defect examination

2. Track record (Including domestic plants, overseas plants, and in other industries)

French nuclear power plant

3. Grounds for and technical issues with regard to possible application to Fukushima Daiichi Nuclear Power Plant

Remote controlled televisual inspection operated in contaminated area

Application task	Possible or not	Notes: reasons etc. (quantitative)
Use in a radiation environment	Yes	Made for that
Use in a high-temperature (60ºC) environment	Yes	Made for that
Access to within pedestal	Yes	
Examination of position/state of fuel debris	Yes	
Adaptation to disclosure of technical information and improvement	Yes	
Dispatch of operating technicians	Yes	

4. Technologies to be developed (Examples)

5. Notes

［書式２－３］セッション２（格納容器の遠隔操作等の走行機器や計測機器に関連する技術）用

技術カタログ	
分類移動装置	狭隘部・管路移動機構
タイトル	能動スコープカメラ
提案者	東北大学／国際レスキューシステム研究機構　田所諭

１．技術内容（特徴、仕様、性能など）

ケーブル表面に繊毛振動駆動の分布アクチュエータを有する自走式のビデオスコープであり，従来のビデオスコープと比較して高い挿入性能を持っている．

・管路（φ3cm）や瓦礫内（隙間幅 3cm）を自走し，数m～数十m奥まで侵入し，内部の撮影等を行うことが可能.

・平地において，勾配登坂（最大 30 度），段差乗り越え（最大 20cm 程度），ギャップ通過（最大 30cm 程度）が可能.

・ケーブルのねじり，先端部の曲げにより，平地や瓦礫内での操縦が可能.

・管路において，他の方法と比べて多数の直角エルボーの通過可能

φ100 で最大 12 個程度（右図），φ50 で最大 5 個程度

・さらに細い管径にも対応可能（開発が必要).

２．実績（国内プラント、海外プラント、他産業での実績を含む)

・建設現場倒壊事故の原因調査に使用し，コンクリート瓦礫内深さ 7m の，柱や梁の亀裂の形状や，コンクリート剥離片断面の撮影を行い，原因究明に貢献.

・管内走行試験では，上記の実績.

・消防庁長官表彰，今年のロボット大賞優秀賞受賞.

３．福島第一原子力発電所への適用可と考える根拠、技術的課題

・適用：管路の点検，管路を通じての炉内の調査・モニタリング

・課題：エルボー多数の管の場合，侵入可能でも，引き抜きが困難になる．除染の課題.

４．開発すべき技術（例）

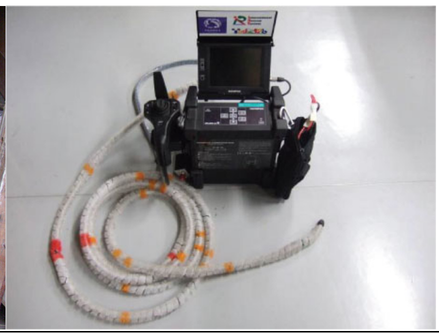
・引き抜きを可能にする技術，管等への挿入を行うためのマニピュレータの開発

５．備考


The New York Times　June 25, 2007

Jessica Kourkounis for The New York Times

Satoshi Tadokoro operates the Active Scope Camera, an optic robot that inches along like a snake.

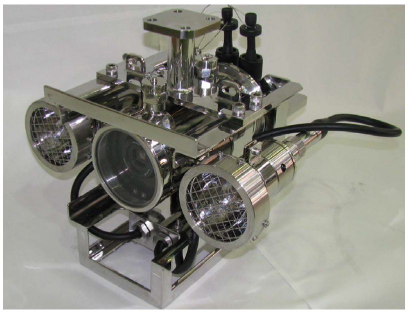


［書式２－３］セッション２（格納容器の遠隔操作等の走行機器や計測機器に関連する技術）用

技術カタログ	
分類移動装置	外観検査装置
タイトル	遠隔操作可能なハイビジョンカメラ
提案者	中部電力(株)・(株)アトックス

１．技術内容（特徴、仕様、性能など）

本外観検査装置は、原子力発電所の燃料プールにて燃料集合体の外観検査ができるように開発されたものであり、市販のハイビジョンカメラを使用し、遠隔にてズーム調整や照明の明るさ調整（ON/OFF 含む）等が可能である。30m までの耐圧性を有している。



２．実績（国内プラント、海外プラント、他産業での実績を含む）

浜岡原子力発電所（試験運用）

３．福島第一原子力発電所への適用可と考える根拠、技術的課題

項　目	適用性	備　考
放射線環境	YES	15Gy/h までノイズの影響はほとんどなし 累積線量 250Gy 程度
高温（60℃）環境	No	40℃まで適用確認
ペデスタルへのアクセス	YES	幅 370×高さ 328×奥行 400mm、重量 20.5kg
位置・デブリ状態の調査	YES	ハイビジョン画像で連続撮影 距離 1.5m・20 倍ズームで 0.3mmφピンホール検出
技術情報等の公開	YES	可能
エンジニアの派遣	YES	可能

４．開発すべき技術（例）

・ペデスタル内部を移動するには駆動機構が必要

・高温環境への適用にあたっては冷却機構が必要

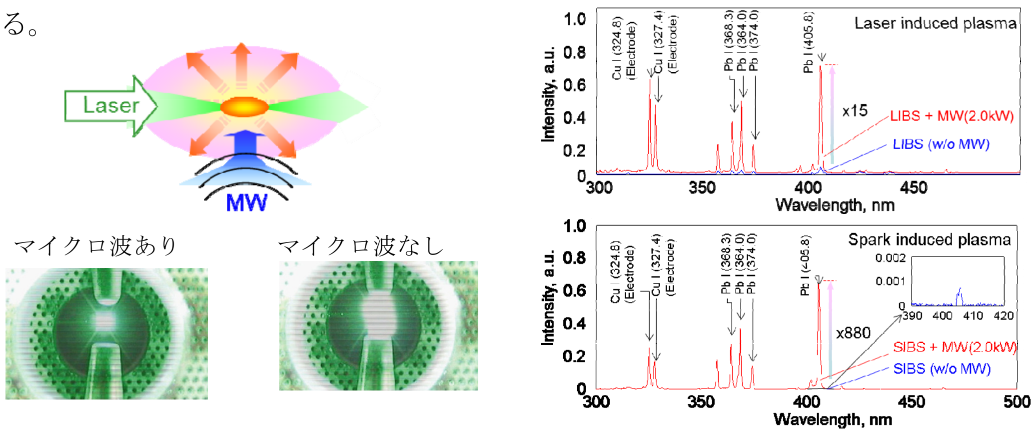
５．備考

参考文献　ハイビジョン画像の原子力発電所への適用（１）燃料集合体番号確認と外観検査への適用, 河村　真吾他, 日本原子力学会 2012 年春の年会予稿集, p189, 2012

技術カタログ	
分類	計測装置
タイトル	マイクロ波支援レーザー誘起ブレイクダウン分光法
提案者	イマジニアリング株式会社

１．技術内容（特徴、仕様、性能など）

レーザー誘起ブレイクダウン分光法（LIBS）は気、液、固体を問わず、プラズマ発光の分光分析から被対象物の含有元素成分を検出し得る技術である。本技術では、レーザあるいはスパーク放電によって誘起したプラズマにマイクロ波を照射することにより、その発光量を大幅に増加させることが可能である。原子炉内のような狭小な空間内の分析には、光学系や機器類を小型化する必要があり、従来の LIBS ではそれに伴う分析感度の低下が予想される。本技術の応用により、原子炉内での元素分析において、高い分析感度を達成する。



マイクロ波により増幅されたレーザープラズマと、その発光スペクトル（レーザー及びスパーク）
レーザーにより誘起したプラズマに、マイクロ波照射を組み合わせると、鉛の発光スペクトルの場合の発光強度がレーザーでは 15 倍、スパークでは 880 倍に増幅（Appl.Opt. 51, B183-191, 2011）

２．実績（国内プラント、海外プラント、他産業での実績を含む）

文部科学省　原子力システム研究開発事業「次世代燃料の遠隔分析技術開発と MOX 燃料による実証的研究」に採用実績あり。

３．福島第一原子力発電所への適用可と考える根拠、技術的課題

放射線環境での使用	可・(否)	実績なし
高温環境での使用	(可)・否	500 ℃以上での使用実績あり
ペデスタル内へのアクセス	可・(否)	移動機構との組み合わせが必要
燃料デブリ位置/性状調査	(可)・否	対象物の元素組成をその場計測可能
技術情報の開示・改造対応	(可)・否	用途に応じたカスタマイズ可能
運転・運用技術者の派遣	(可)・否	福島第一原子力発電所に派遣可能

４．開発すべき技術

移動機構、耐放射線ファイバとの組み合わせが必要。耐放射線対策が必要。

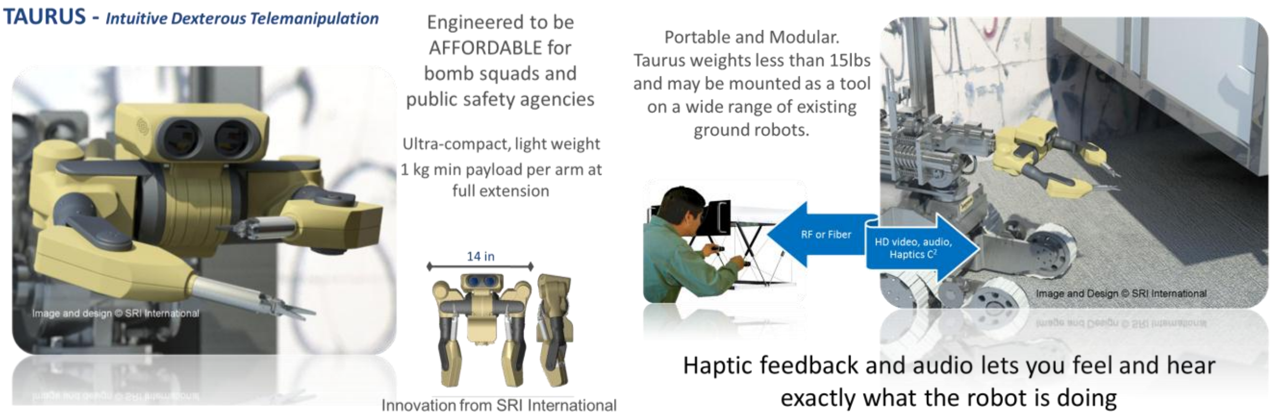
５．備考

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Remote-Telepresence Robot
Title	TAURUS - Intuitive Dexterous Telemanipulation
Proposed by	SRI International

1. Technical description (Advantage, Specification, Performance)

Taurus robot (recently developed by SRI) is a high fidelity telemanipulation tool with a 3D HD display. Taurus was originally designed for bomb squad technicians to remotely engage with improvised explosive devices. It enables surgical-like precision in a modular, portable, compact frame. Weighing less than 15 lb, Taurus may be used as a tool on the end of an existing robot, or it can be easily integrated into portable formats or other systems.



Taurus is based on more than 20 years of experience in the deployment of dexterous telemanipulation tools. In the early 1990's, SRI developed the M4 platform as the first demonstration of dexterous telemanipulation. This system was commercialized to become the daVinci surgical robot system, which is now used in more than 300,000 surgical procedures a year worldwide.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Taurus capabilities are based on a world-wide proven and deployed remotely-controlled robotic technology

3. Applicability to Fukushima site, Technical challenges

Taurus may be used as a tool on the end of an existing robot, or it can be easily integrated into portable formats or other systems.

4. Technology Development (Example)

As a world leading independent research and technology development organization, SRI can flexibly deploy its proven robotic-innovation capabilities to meet the needs and the realities of this project.

5. Note

SRI performs client-sponsored research and development. And can develop various other robotic technology solutions as required for Fukushima Daiichi Nuclear Power Plant.

[Format 2-3] Session2　Remote-control operation machine and measurement equipment for CV inspection

［書式２－３］セッション２（格納容器の遠隔操作等の走行機器や計測機器に関連する技術）

Technical Catalogue　/　技術カタログ	
Mobile device classification 分類移動装置	On a mobile support モバイル･サポートに取り付け
Title タイトル	**Scan 3D & Gamma Camera Inspection Tools** **3D スキャン＆ガンマカメラによる調査技術**
Proposed by / 提案者	AREVA （アレバ）

1.　Technical description (Advantage, Specification, Performance)

１．技術内容（特徴、仕様、性能など）

In TEPCO's roadmap, first step towards removal of debris is inspection of the Reactor Buildings. But, reactor buildings are very damaged:

- Construction Drawings are useless.
- State of reactors roof is difficult to know
- State of inside of R/B is almost impossible to know
- Dose rate cartography is imprecisely known.

Besides, before any Operation, it is mandatory to elaborate scenario based on:

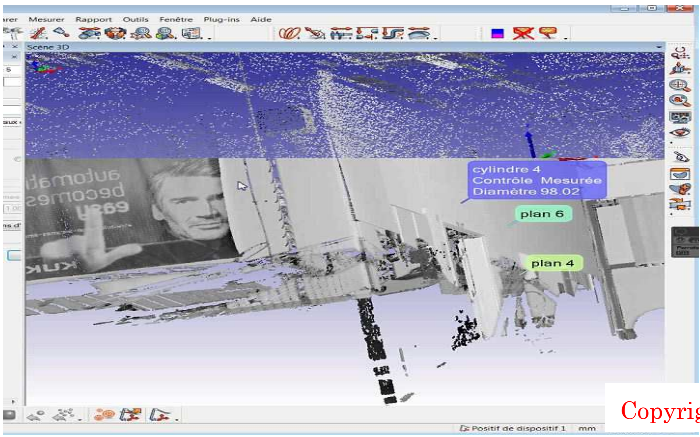
- Knowledge of the further works environment (scrap, rubbles, pipes…)
- Knowledge of activity dose rate environment.

Scan 3D and Gamma Camera tools can be very helpful in the inspection step of the reactors buildings. Combination of the two technologies is a very good solution to retrieve accurate data for the thinking of the management of NPP decommissioning.

3D スキャン＆ガンマカメラを組み合わせことによって、原子炉建屋の現状を把握することができ、デコミを検討する際に有効な技術である。

1- SCAN 3D

The Scan 3D technology allows the reconstruction in one “cloud of pictorial points” (scatter plot images) of the environment thank to one moving laser ray and the measurement of the delay between sending and receiving back the laser to the scan equipment.
レーザー光線の単一移動とスキャン装置のレーザー送受信間の時間差測定で、3D スキャンのテクノロジーにより、ピクトリアル・ポイント・クラウド（散発的にプロットを行ったイメージ）にて周囲の状況の再構築が可能である。
As shown is the picture below, the outlet view of the laser can be used directly to see images and environment. Gray points in the picture below are the direct output of the laser measurement. Blue is the software screen (so where no measurement had been done).
下記の写真に示す通り、レーザーのアウトレット・ビューを用いて映像と周囲の状況をじかに観察することができる。下記の写真の灰色の点はレーザーによって直接測定した結果である。青色は（測定が行われなかった地点を示す）ソフトウェア上の画面である。
The scan 3D is a 360°scan and can scan between 0.5 to 200 m length with a precision around 2 mm in the first meters of scan.



Each 360°scan is performed in around 10 minutes.
As the outlet is a 2D image, several scan are needed from several positions in the room to obtain a 3D model of the room. In that case several scan of 10 minutes are needed for a full 3D scan of one given room.

After scanning, images can be reconstructed in different ways:

- Scatter plots images are directly used with the possibility to make measurement, interactive panoramic visit of the scanned room… which is probably sufficient in most of our cases.

- Possibility to combine several scans to make a 3D scan (around 20 min of computer works)
- Possibility to make reverse engineering until CAO 3D mechanical models. This can take several days of work.

2- Gamma Camera

Gamma Camera technology allows dose rate mapping.ガンマ線カメラのテクノロジーによって放射線マップの作成が可能である。

This technology is based on more than 15 years of experience and use.この技術は 15 年以上の使用経験を持つものである。

Currently, AREVA Canberra subsidiary is working on a concept of a little Gamma Camera called GAMPIX which is more compact and which weight is less than 2kg (2, 4 or 8 kg with shielding depending of the ambient dose rate). This new gamma imager is so very adapted for robotic application.

現在 AREVA の子会社である Canberra は GAMPIX と命名する小型ガンマ線カメラの開発を進めているところである。GAMPIX ははるかにコンパクトで、重さは 2kg 以下（周囲の線量に対するシールド付きで 2kg、4kg、8kg）である。新製品の本ガンマ線カメラはロボット使用には非常に適している。

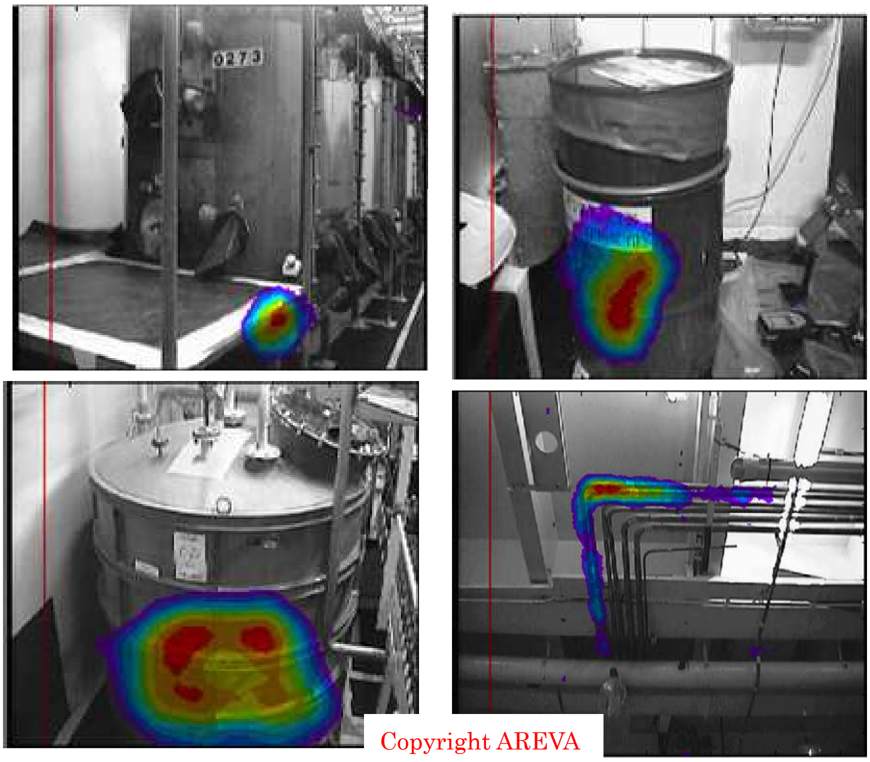
Photo on the left is photo of previous version (CARTOGAM) of gamma imager. Photo on the right is photo of prototype constructed this morning.

For a one direction measurement, the acquisition time is only a few seconds. This had been tested in ambient from few nSv/h to more than 5 Sv/h.

3- Gamma mapping over Scan 3D

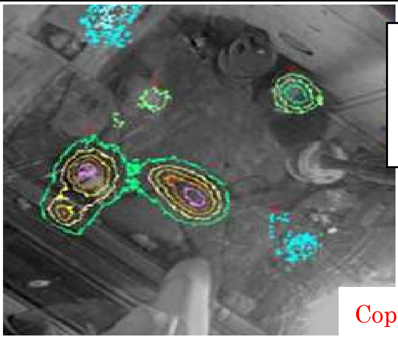
The aim of using the both technologies together is to retrieve information of dose rate measurement over pictures issued by scan 3D as the example below (with gamma camera dose rate mapping over a picture).2つのテクノロジーを組み合わせて用いるのは下記の例（ガンマ線カメラが映像上に捕らえた放射線マップ）が示す通り、3Dスキャンが送り出す写真を基に線量に関する情報を入手するためである。

This is a very “speaking” picture of where is the contamination in the room to decontaminate (drums, pipes…), like in the picture below.



2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Gamma Camera is a technology development in years 1980 and already wide spread in Japan and overseas.ガンマ線カメラのテクノロジーは1980年代に開発された技術で、日本及び海外で広く普及されている。



Example of Gamma Camera Use in a CEA active cell decontamination in France

3. Applicability to Fukushima site, Technical challenges

Not only, these tools are applicable and useful in Fukushima situation, but this is for this kind of situation than those tools are developed.

Indeed, in a post accident situation more than any other situation it is mandatory to make the basic data of the problem clear to know where to start towards the resolution of the issue.

Making a combination of the use of scan 3D and Gamma Camera is an innovation.

Development had started at the beginning of 2011 and the technology should be ready in 2012.

4. Technology Development (Example)

5. Note

Scan 3D can also be used with other kinds of Irradiation mapping device using other technology like tomography for example.

[Format 2-3] Session2　Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	
Title	BIMDI cumulated dose measurement
Proposed by	AREVA and partner ERMES

1.　Technical description (Advantage, Specification, Performance)

BIMDI solution is based on small and cheap electronic probes to be fixed on any intervention device in high active area. BIMDI ソリューションは安価な小型電子プローブを取り付け、その装置で線量の高い場所で作業を行うことを目的にしている。

This device allows the measurement of dose rate and total cumulated dose in a very high active area. It can measure cumulated dose from 0 to 10 kGy and developments are under validation for 0 to 1.6 MGy.　同装置によって非常に線量の高い場所で瞬間線量及び累積合計線量の測定が可能である。累積線量の測定は 0kGy から 10kGy までであり、0kGy から 1.6MGy まで測定可能な新規開発品は現在認定中である。

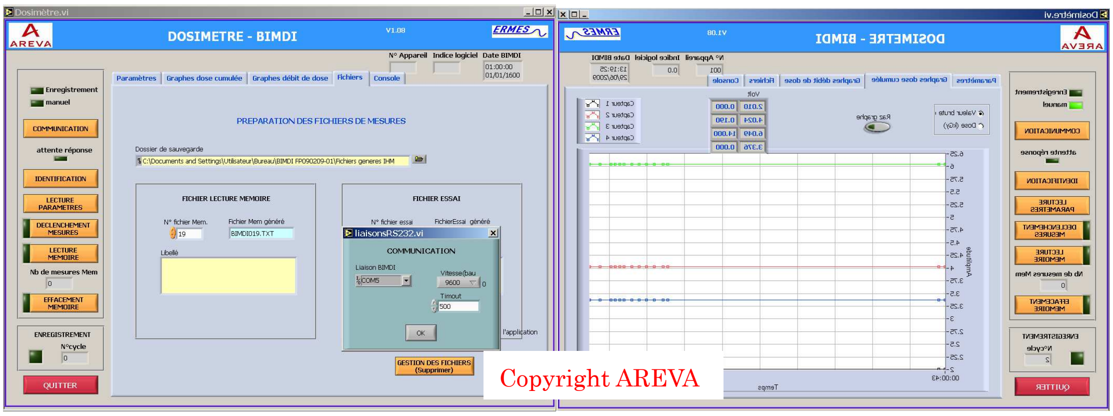
The device consists in several probes for dose detection along a chain and a little electronic box placed behind the wall in a non active area.装置は幾つかの線量検知プローブから成るもので、同プローブをチェーン上に、また非放射能区域の壁の後ろに設置した小型電子ボックスに取り付ける。

Probes chain:

Box:

The electronic box is autonomous for more than 3 weeks and can record in the meantime all the values.電子ボックスは最低 3 週間充電の必要がなく、その間必要な数値をすべて記録することが可能である。

This equipment can also be linked to a personal computer with its data management software developed for this application.



Sensor technology is RADFET (Radiation Sensing Field effect Transistor), which report dose rate by voltage variation.センサーの技術は RADFET (Radiation Sensing Field effect Transistor)で、電圧変動にて線量を伝達するものである。

The sensors had been characterized in test validated by both CNRS (French National Research Agency) and IRSN (Technical Body of the French Safety Authority).センサーは CNRS (仏国立研究所) and IRSN (仏安全当局の技術部門)の両機関の認定試験を受け、合格している。

This system has been developed by AREVA.本測定システムを開発したのは AREVA である。

APPLICATIONS:

Schedule preventive maintenance of equipments: this sensor can be attached to any equipment in high active areas (cameras, robots, remote controlled robotic arms or tools). It then allows knowing the overall dose received by any equipment. Maintenance of these tools can therefore be planned more easily and efficiently: instead of having unexpected equipment failure, know when the equipment will fail because it has received too much dose.予定される装置の予防保全：このセンサーは高線量区域で用いる全装置（カメラ、ロボット、遠隔操作ロボット・アームやツール）に取り付けられる。また装置が浴びた合計線量も知ることも可能である。従って、上記ツールの保修をより計画的に、より効率的に行うことができる。装置の突然の不具合に遭遇することなく、過度に線量を浴びた装置がいつ故障するか予知が可能である。

It is cheaper and much convenient (smaller) than using conventional nuclear measurement devices.従来の放射能対応測定機器に比べ、より安く、より小型で、はるかに便利である。

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Monitoring of robotic in AREVA La Hague plant most active area.　AREVA ラアーグ工場の最も線量の高い区域におけるロボットの監視

3. Applicability to Fukushima site, Technical challenges

Installation in mobile robots　移動ロボットへの取り付け

Implementation on any remote controlled equipments in high active area　高線量区域にある遠隔操作装置への応用

4. Technology Development (Example)

None

5. Note

[Format 2-2] Session1: Remote-control decontamination

Technical Catalogue	
Mobile device classification	Mobile Robot
Title	Water Blast Remote Controlled System
Proposed by	ATOX- AREVA

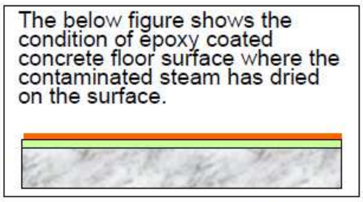
1. Technical description (Advantage, Specification, Performance)

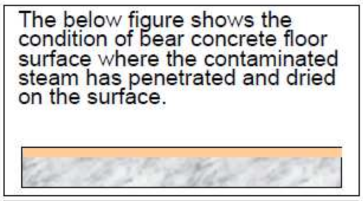
This tool is fitted for decontamination and removal of contaminated concrete.本ツールは汚染コンクリートの除染及び除去に適しています。

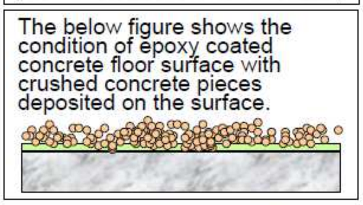
Water Blast process treats contaminated concrete, which is an issue on Fukushima Daiichi NPP dismantling process.ウォター・ブラースト・プロセスでも汚染コンクリートの処理が可能ですが、福島第一原発では問題があると思います。
Indeed, Hydro demolition is a blasting process based on mechanical removing of concrete thanks to high pressure water.ハイドロ・デモリッションは高圧水を用いてコンクリートを機械的に除去するブラースティング方式です。

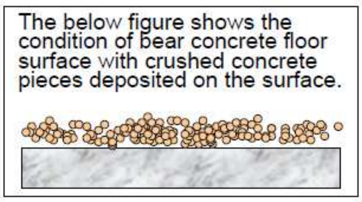
With one unique device including several types of nozzles, and only modifying operational conditions (pressure, flow rate), it is possible to perform three types of operation:数種類のノズルを含む他に類のないデバイス 1 個を用いて、また使用条件（圧力、流量）を変えることによって、下記に述べる 3 種類の作業が可能です。

- 1/ High pressure water jet surface decontamination cleaning of lining/painted concrete,高圧ウォーター・ジェット洗浄によって行うコーティング、塗装コンクリートの表面除染
- 2/ Removal of contaminated painting or lining from concrete surface,コンクリート上の塗装、またはコーティングされた汚染表面の除去
- 3/ Hydro demolition, i.e. removal of a few mm to a few cm of contaminated concrete, when concrete does not have lining or when this lining had been damaged due to extreme conditions in R/B such as radiation, high temperature and moisture.ハイドロ・デモリッションは、コンクリートにコーテ









ィングが施されてない場合に、もしくは原子炉建屋（R/B）が照射、高温、高湿度など極端な条件下にあり、コーティングが損傷している場合に、汚染コンクリートから数 mm から数 cm 取り除く方法です。

In that case, water blast can be used for any of the 4 situations of concrete which had been described (see opposite) in the document “Development of remote Decontamination Technology inn the Reactor Building” of March 14th 2012 for the “international symposium on the Decommissioning of TEPCO’s Fukushima Daiichi NPP units 1-4”.このような場合、東電福島第一原発 1-4 号機の除染・解体作業に関する国際シンポジウムのために 2012 年 3 月 14 日に作成された図書“原子炉建屋における遠隔操作で行う除染テクノロジー”に記載されたコンクリートの 4 種類のどの状況でもウォーター･ブラーストの使用は可能です。

Main advantages of the process:

- One equipment = Three main operations of dismantling 装置 1 台で 3 種の解体作業の実施
- Remote controlled operation available 遠隔操作による作業が可能
- One of the easiest heavy decontamination process to implement 深刻な汚染を比較的簡単に実施できる方法のひとつです。
- For scabbling and decontamination:削り取り及び除染
  - innocuousness in regards of iron in concrete コンクリートに含まれる鉄筋の処理に際しては害は発生しない。
- Only two waste:2 種類のみの廃棄物の発生
  - Concrete part removed from decontaminated surface 汚染された表面から取り除かれたコンクリートの断片
  - Liquid water effluents that can be treated with the existing water treatment facilities on site. Water is easier to manage than off-gas, since it flows down by gravity.廃液は現存する工場内廃水処理施設で処理することが可能です。廃水は重力の原理で流れて行くため、廃ガスの管理よりは容易です。

Solid concrete and water retrieved are then separated with a nuclearized centrifugation process to separate solid waste to dispose and water effluents to recycle for hydro demolition or to send to contaminated water tanks.
2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.) Classic operation in civil works. Nuclearization of many decontamination tools in AREVA facilities.
3. Applicability to Fukushima site, Technical challenges Possibility to apply the technology in a mobile robot to perform water blast process in Reactor with some adaptations, such as adaptation on a remote controlled robot.
4. Technology Development (Example) Some adaptation of existent devices are required: - Modification of nozzles is needed. - Modification of vacuum device and further separation solid/liquid is needed. - … These technology developments and remote controlled adaptation could be performed in collaboration by AREVA and ATOX on a “commercial base robot”. General robotics remote controlled know how of ATOX and nuclear know how of AREVA will be used to develop a final solution totally remote controlled and adapted to specific Fukushima needs… As an illustration, such robotic concept below (left) from ATOX can be used as principles for adaptation of water blast system and vacuum device system on a commercial robot (e.g robot below right).

5. Note

[Format 2-2] Session1: Remote-control decontamination

Technical Catalogue	
Mobile device classification	
Title	**NiThrow™ solution**
Proposed by	AREVA NC JAPAN PROJECTS

1. Technical description (Advantage, Specification, Performance)

Part of decommissioning work in Fukushima will required tools for decontamination and management of contaminated concrete.福島における解体作業に関しては、汚染コンクリートの除染及び管理用に一部ツールが必要になります。

NiThrow™ is a nuclearized solution for concrete scabbling, cutting and decontamination of a technology based on the spraying of liquid nitrogen at a temperature of -140℃ and a pressure of 3 500 bars NiThrow™方式とはコンクリートを削り取り、切断し、除染する方法です。同方式は、温度-140℃、圧力 3 500 バールで液体窒素を吹き付けて除染するテクノロジーです。.

This process can be useful for the three main process of decommissioning:この技術は解体作業における下記の 3 種類の主要プロセスに有用です。

- Concrete Scabbling　コンクリートの削り取り
- Cutting process　コンクリートの切断
- Decontamination works　コンクリートの除染作業

More photos are given in format 3.

Concrete Scabbling:

- Depth of cut from 1 to 30 mm (function of time and concrete type).
- From 1 to 8 m²/h of scabbling (and around 30 L/h of concrete removed).
- Works on any types of concrete (vibrated/non vibrated, high/low densities).

Cutting:

- Cutting of all types of material (stainless steels, bitumen…) with or without abrasives (depending on the hardness)
- 50 mm depth for stainless steel, 200mm for bitumen
- Productivity of 4 cm/min for stainless steel (50 mm depth).

For hardest type of material (stainless steel e.g.), an additional abrasive material have to be added to nitrogen to perform efficient cutting.

Decontamination:

- Can be used for various types of contamination (paints, grease, rust…)
- Productivity:
    - Over 5 m²/h for paints
    - Over 10 m²/h for grease, rust…

Key figures:

Operating pressure:	800 to 3,500 bar (11,603 to 50,763 psi)
Operating temperature:	-130 to -150 °C (-202 to -238 °F)
Consumption of liquid nitrogen:	~ 20 L/min (0.7 CFM)
Size of pressurization skid:	2,920 x 1,270 x 1,651 mm (115 x 50 x 65)
Weight of pressurization skid:	3,600 kg (8,000 lbs)
Power supply:	400 V, Three-phase, 150 kVA

Remote controlled operation:　遠隔操作で行う作業

Remote controlled operation is available with specific carrier. One carrier (3 in photo below) has been developed for an AREVA project. A carrier may be developed for a specific customer need.特定のキャリアーを使用して遠隔操作作業を行います。AREVA プロジェクト用にキャリアー1 台（下の 3 写真）を開発しました。もし顧客の特別な二―ズに応じて、新しく開発することも可能です。

Distance of 100 m is acceptable with specific high performance insulation of nitrogen pipes (photo 4)絶縁を施した.高性能の窒素パイプ（写真 4）を 100m の長さで納入できます。

Remote controlled sucking of retrieved parts of support thanks to an adapted capping (1) of the nitrogen gun nozzle (2).窒素用ガン・ノズルを先端に装着することによってコンクリートから削り取った断片を遠隔操作で吸引し、回収することも可能です。

Main advantages of the process:　この方式の主な利点

- Single operation for three main tasks of D&D　D&D（解体）の主要な 3 件の作業を 1 回の作業で処理可能
- Dry process with no effluents generated　乾式であるため、廃液が発生しない。
- For scabbling and decontamination:　削り取り及び除染に関しては
    - easy to deal with irregularities　でこぼこがあっても対応可能
    - innocuousness in regards of iron in concrete　コンクリートの中に鉄筋を処理しても無害
- For cutting:切断に関して
    - No hot spots　ホット・スポットは存在しない。

- Possible use with Mg, Na Li (sensitive materials)（注意を要する元素である）Mg、Na Li に対しても使用可
2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.) Non nuclear use of this solution in France (in R&D Center) and in United States for cleaning of heat exchangers (not performed by AREVA). Nuclear development made in France with Air Liquide. Real test had already been performed in SICN Veurey, operated by AREVA . New projects will use this Nithrow™ solution in 2012 and 2013, operated by AREVA .
3. Applicability to Fukushima site, Technical challenges Applicable to Fukushima. Remote controlled solution until 100 meter distance.
4. Technology Development (Example) Optimization of the remote controlled carrier to fit the specific needs and constraints of Fukushima Daiichi decommissioning works.
5. Note This solution is proposed thanks developments made by AREVA with partners.提案するこの方式は AREVA が協力会社の支援を得て開発したものです。 The experience gained by AREVA in nuclear testing of the solution makes AREVA and partners the only one able to operate this solution in active areas.この方式に関して、AREVA は放射能環境対応テストを行い、経験を積んだ結果、AREVA と協力会社はこのやり方で唯一高線量区域で作業を行える企業になったものです。

[Format 2-3] Session2　Remote-control operation machine and measurement equipment for CV inspection

［書式２－３］セッション２（格納容器の遠隔操作等の走行機器や計測機器に関連する技術）

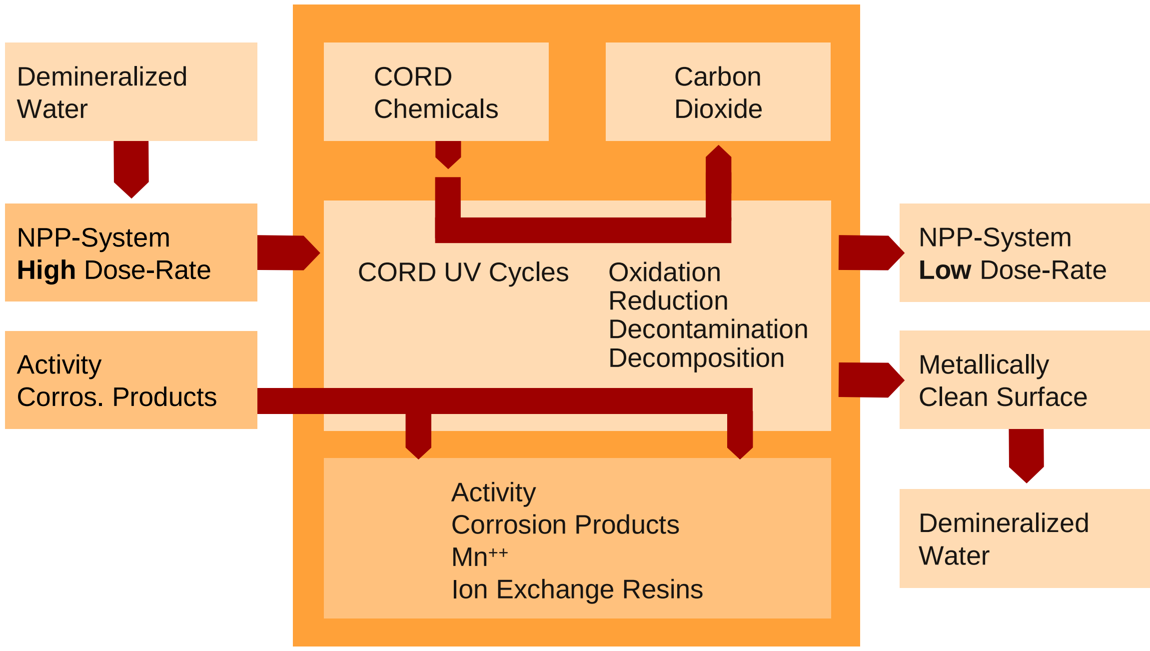
Technical Catalogue　/　技術カタログ	
Mobile device classification 分類移動装置	
Title タイトル	**Chemical Decontamination CORD®　Family**
Proposed by / 提案者	AREVA （アレバ）

1.　Technical description (Advantage, Specification, Performance)

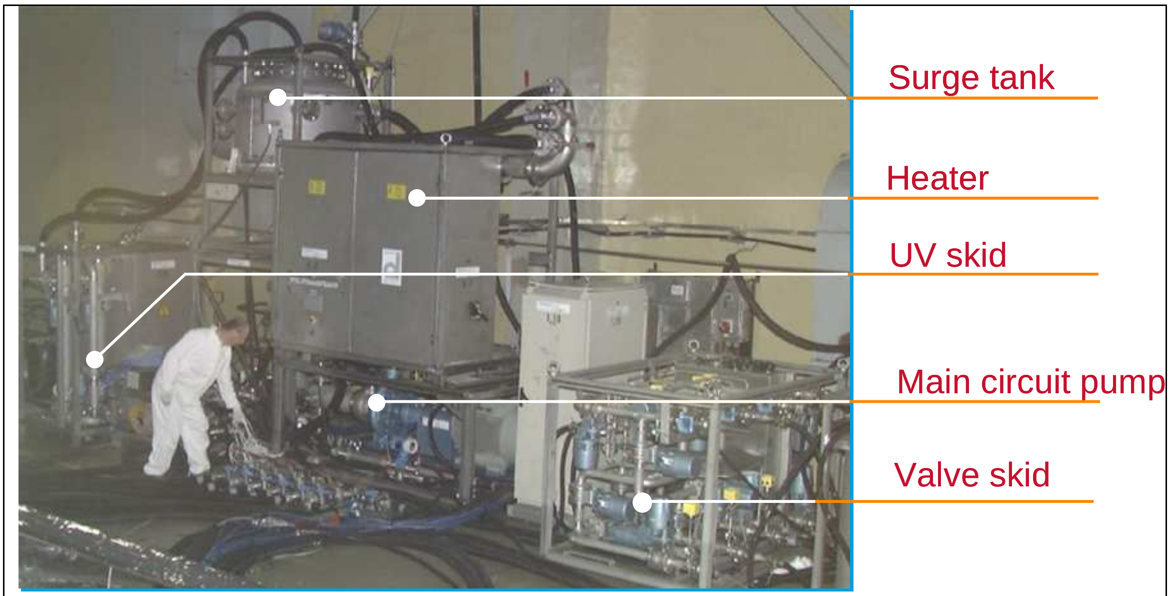
１．技術内容（特徴、仕様、性能など）

Description:
Chemical decontanination to remove contamination from inner surfaces of components and systems inclusive alpha conatmination

Operation principle:
Decontamination equipment (AMDA®) is connected with the system to be decontaminated. In the decontamination circiut chemical for decontamination are injected and the dissoluted activity / contamination is transferred on ion-exchange resin.



CORD Family Logistics



Example for AMDA Installation at site

The decontamination can placed in a optimized way, that dose exposure is minimized for operating personnel. All main functions are remote controlled.

With CORD Family the Decontamination Concept for Decommissioning (DCD) can be applied:

- Removal of oxide layers with activity / contamination
- Initiate controlled base metal removal with high accurcay
- Removal of alpha contamination and losse contamination

Advantages:

- Decontamination concept tailored to actual task with respect to chemistry and process engineering concept
- High flexibility
- Strict application of ALARA principle
- High decontamination factors achievable for alpha, beta and gamma nuclides
- Low secondary waste generation
- No chelates on ion exchange waste

Only one fill of system necessary due to regenerative deconatmiantion process

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

- Decontamination factors up to 1000 possible

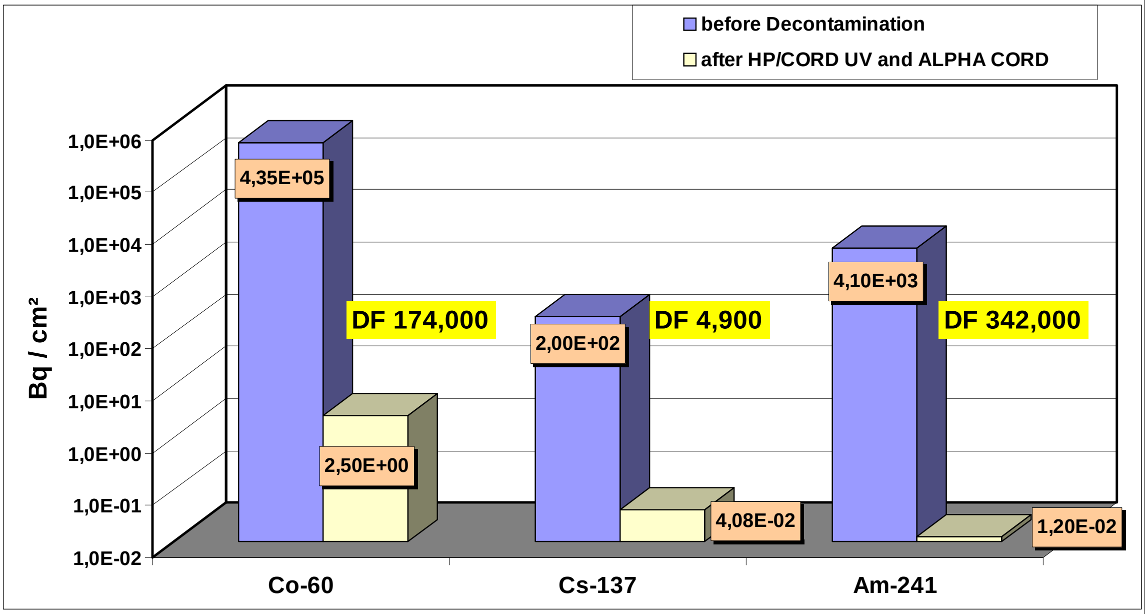
	Pu-239 & Pu-240 / (Bq/cm²)	**Am-241 / (Bq/cm²)**	**Cm-243 & Cm-244 / (Bq/cm²)**
Original	7,72E+00	5,43E+01	5,95E+00
after HP CORD UV	5,56E-01	2,64E+00	1,74E-01
after CORD Alpha	6,15E-03	2,72E-02	1,34E-03
Decon Factor	**1254**	**1996**	**4453**

DF Result especially for alpha nuclides with application DCD

Cut Sample	1		2		3	
	Act bef. Bq/g	DF	Act bef. Bq/g	DF	Act bef. Bq/g	DF
Total act	8.7 E5	6200	2.2 E5	1955	2.3 E5	850
Co-60	8.8 E4	4700	2.3 E4	540	2.2 E4	470
Fe 55	3.4 E5	18200	6.5 E4	4500	7.3 E4	3100
Ni-63	3.9 E5	105000	1.1 E5	14000	1.2 E5	7100
U-238	4.0 E-1	1100	1.0 E-1	513	5.0 E-1	1200
Pu-241	3.9 E4	> 10000*	1.2 E4	> 10000*	6.6 E3	> 10000*

*below detection level

DF result on cut samples for decon at heavy water reactor MZFR Germany



DF result for decontamination in German BWR Lingen

CRD Housings (bottom of RPV) after decon at Unit 2

Core shroud stand (bottom of RPV) after decon at Unit 2

Metallically clean Surfaces after decontamination in Swedish BWR Barsebäck

Dose rates before/after decon and DF achieved:

- Dose rates before: 730 µSv/h
- Dose rates after: 29 µSv/h
- Achieved DF (61 measuring points): 286

Release: 2.3 E12 Bq, 30 kg corrosion products
Personnel dose savings: 20 000 mSv
DF 20 to > 1000, IX resin waste: 2.5 m^3
Smearable contamination after FSD at RPV bottom: 4 Bq/cm^2

FSD at Swedish BWR Oskarshamn 1

Results:

before FSD: ~20–25 mSv/h

After FSD: ~0,015–0,02 mSv/h without interferences

- decontamination for decommissioning with CORD Family and AMDA is performed since 1986

NPP	NPP Type	Application Time	Decontamination Process	System (Extent of Decontamination)
FR 2, Germany	PWR (Siemens)	1986	HP/CORD	Primary Loop
MOL/BR3, Belgium	PWR (Westinghouse)	1991/92	HP/CORD	FSD, including SG, RPV and auxiliary systems
VAK, Germany Kahl	BWR (GE)	1992/93	HP/CORD D UV	FSD, incl. SG (superheater), RPV and auxiliary systems
NPP Rheinsberg	VVER (Russian)	1994	HP/CORD D UV	Steam generator
MZFR, Germany	PWR heavy water (Siemens)	1995	HP/CORD D UV	FSD including SG and auxiliary systems (5 systems)
KWW, Germany Würgassen	BWR (GE)	1997/98	HP/CORD D UV	FSD without RPV (11 systems)
ConnYankee, USA Haddam Neck	PWR (Westinghouse)	1998	HP/CORD D UV	FSD without RPV
KWL, Germany Lingen	BWR (GE)	2001	HP/CORD D UV	Auxiliary systems (4 systems)

NPP	NPP Type	Application Time	Decontamination Process	System (Extent of Decontamination)
Caorso, Italy	BWR (GE)	2003	HP/CORD UV	Recirculation, RWCU
Trino, Italy	PWR (Westinghouse)	2004	HP/CORD UV	Steam generators and loop sections
Stade, Germany	PWR (Siemens)	2004/05	HP/CORD UV	FSD, primary circuit incl. RPV and auxiliary systems
Obrigheim, Germany	PWR (Siemens)	2007	HP/CORD UV	FSD, primary circuit incl. RPV and auxiliary systems
Barsebäck 2, Sweden	BWR (ABB)	2007	HP/CORD UV	FSD including RPV and auxiliary systems
Barsebäck 1, Sweden	BWR (ABB)	2008	HP/CORD UV	FSD inlcuding RPV and auxiliary systems
Chooz A, France	PWR (Westinghouse)	2011/12	HP/CORD D UV	Steam generator, pressurizer loops
Unterweser	PWR (Siemens)	2012	HP/CORD UV	FSD inlcuding RPV and auxiliary systems

3. Applicability to Fukushima site, Technical challenges

4. Technology Development (Example)

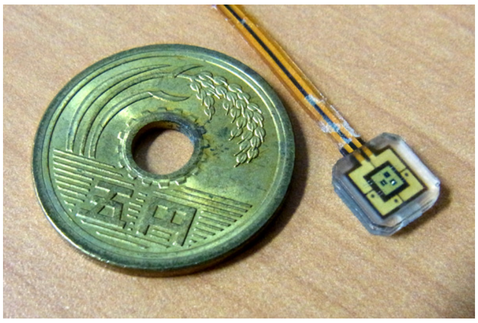
5. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Classification	Measuring device
Title	Small and thin 3-axis force sensor (Shokac Chip)
Proposed by	Touchence Inc.

1. Technical description (Advantage, Specification, Performance)

Shokac Chip is the smallest and thinnest 3-axis force sensor commercially available ever. It can detect pressure and two-axis shear stresses applied to its surface. Net rated loads are adjustable by changing the sensor size and/or selecting the covering material for which we have two choices now, epoxy resin and silicone rubber, and they would increase.



Shokac Chip SE-07 covered by epoxy resin

Main specifications of Shokac Chip SE-07

Item	Specifications
Dimensions	W 7mm x L 7mm x H 2mm (except cable)
Weight	< 1g
Net rated loads	Fx, Fy = 50N, Fz = 100N
Maximum loads	Fx, Fy = 100N, Fz = 350N

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

No application to actual plants or other industries.

3. Applicability to Fukushima site, Technical challenges

Applicable issue	Applicability	Remarks and reasons (quantitatively)
Usability under a radioactive environment	No data	We have not tested yet.
Identification of the leak location under clouded water	Yes	We tested and confirmed the feasibility of measuring water flow with Shokac Chip covered by silicone rubber in lab experiments.
Correspondence to the disclosure of technical information and remodeling	Yes	Customization according to the intended purpose is possible.

4. Technology Development (Example)

We have not tested under a radioactive environment yet. It is necessary to combine this sensor with traveling or scanning mechanism to identify the leak location under clouded water.

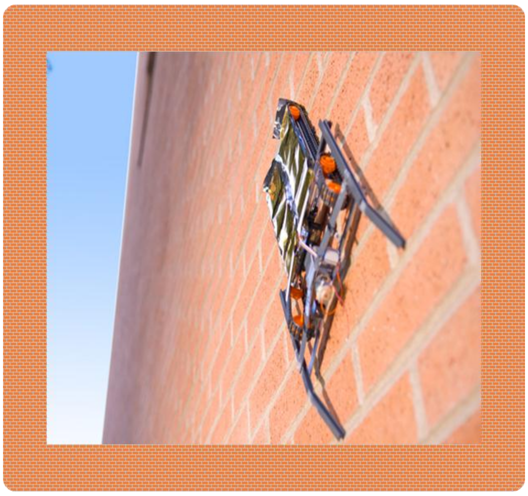
5. Note

[Format 2-3] Session2　Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Wall-climbing robots
Title	Electroadhesive Wall-Climbing Robots
Proposed by	SRI International

1.　Technical description (Advantage, Specification, Performance)

SRI has developed a novel electrostatic clamping technology called Electroadhesion (EA). Wall-climbers



powered by compliant electroadhesion, an electrically controllable adhesion technology.　Wall-climbing robots scale vertical surfaces by virtue of electroadhesion, which involves inducing electrostatic charges on a wall substrate using a power supply connected to compliant pads situated on the moving robot. SRI has demonstrated robust clamping to common building materials including glass, wood, metal, concrete, etc. with clamping pressures in the range of 0.5 to 1.5 N per square cm of clamp (0.8 to 2.3 pounds per square inch).

2.　Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Applications of wall-climbing robots—a DARPA-funded project—address an eclectic array of business, military, civilian, and consumer needs.

3.　Applicability to Fukushima site, Technical challenges

The technology is readily scalable to larger or smaller sizes / weights, from milligrams to several hundred kilograms. Electroadhesion (EA) has extremely low power consumption measured in microWatts; perch times of decades appear feasible. EA wall-climbing robot technology has demonstrated robust clamping to common building materials including concrete walls and metallic surfaces. .

4.　Technology Development (Example)

As a world leading independent research and technology development organization, SRI can flexibly deploy its proven robotic-innovation capabilities to meet the needs and the realities of this project.

5.　Note

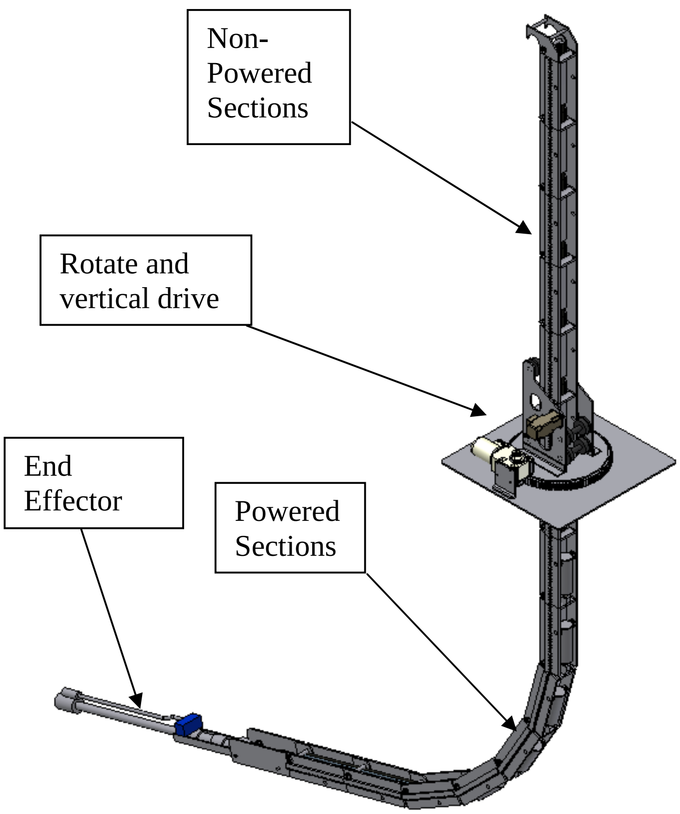
SRI performs client-sponsored research and development. And can develop various other robotic technology solutions as required for Fukushima Daiichi Nuclear Power Plant.

Technical Catalogue	
Classification	Working Mechanism
Title	Link Manipulator (Linkman)
Proponent	James Fisher Nuclear Ltd

1. Technical Details (features, specification & performance)

Key features comprise:

- Hydraulic fluid water
- IP 68 rated
- Dia 270mm deployment aperture
- External, remote valve pack
- Radiation tolerant



Standard System Configuration

Vertical reach	5m
Horizontal reach	4m
Rotation	360^{o}
Payload	50Kg
Operating Pressure	210 Bar
Operating Modes:	Individual joint control Resolved tip motion Rate control Teach & repeat (Option) Collision Avoidance (Option)

2. Past Application (including past applications at domestic plants, foreign plants, & in other industries)

Designed for sludge / resin tank internal inspections on UK Magnox stations.

3. Reasons to be considered as applicable to Fukushima Daiichi Nuclear Power Station, along with technical issues.

Applicable Use	Applicability	Remarks & Reasons
Usability in a radioactive environment	Yes	Radiation resistant specifications. Electronics mounted remote from the in cell arm.
Usability in a high temperature environment (60^{0}C)	Yes	Design criteria: 10^{0}C - 60^{0}C
Access to the inside of the PED	Yes	Access to the inside of the PCV via a vertical Dia 270mm penetration.
Investigation of the position/condition of fuel	Yes	Potential to grip & manipulate fuel or use in conjunction with CCTV camera / radiation detector.
Correspondence to the disclosure of technical information & remodeling	Yes	Potential to customize a standard machine to meet customer specific requirements.
Dispatch of operation engineers	Yes	Deployment of manipulator drivers to Fukushima Daiichi Nuclear Power Station is possible.

4. Technologies To Be Developed

ModuMan LInk may be fitted with a diverse suite of instrumentation (radiation detectors / CCTV cameras / temperature & humidity probes etc) to enable the characterization of fuel debris. This instrumentation is available for installation onto the manipulator by JFN.

5. Remarks

The manipulator operates via a series of powered and non-powered structural links. Articulation is facilitated via standard hydraulic rams in the powered links forcing each limb section to rotate about its end pivot. Rotation is via a slew ring assembly mounted over the appropriate access way and vertical movement is achieved via a rack and pinion drive. End effectors can be utilised with services deployed down the arm and can be pivoted via an additional actuator up to 90°. As the arm sections are withdrawn they can either be rolled onto a suitable deployment drum or detached via removable pins.

Technical Catalogue	
Classification	Working Mechanism
Title	Light Duty Hydraulic Manipulator (ModuMan 25)
Proponent	James Fisher Nuclear Ltd

1. Technical Details (features, specification & performance)

Standard System Configuration

Manipulator Joints/Degrees of Freedom:

Rotation	+/- 185^{o}
Vertical Movement	7 metres
Shoulder Movement	+90 -20 ^{o}
Elbow Movement	+180 -30 ^{o}
Wrist Pitch	+/-60 ^{o}
Wrist Rotate	+/-90 ^{o}
Tool Nod	+100 ^{o}
Toll Package Rotate	+/- 90 ^{o}
Jaw Open and Close	

Key features comprise:

- Deployment via reactor standpipe
- Services for Ultrasonic Weld Inspection Modules
- Remote Joystick Operation
- Powered from 110V Single Phase Supply,
- Self contained tap water hydraulic system.
- Standard 19" Rack control system
- Operating Modes:
- Individual joint control
  - Resolved tip motion
  - Rate control
  - Teach & repeat (Option)
  - Collision Avoidance (Option)

2. Past Application (including past applications at domestic plants, foreign plants, & in other industries)

Reactor internal pressure vessel surveys (Magnox) & solid ILW waste retrieval & segregation operations at Sellafield Ltd UK.

3. Reasons to be considered as applicable to Fukushima Daiichi Nuclear Power Station, along with technical issues.

Applicable Use	Applicability	Remarks & Reasons
Usability in a radioactive environment	Yes	Radiation resistant specifications. Electronics mounted remote from the in cell arm.
Usability in a high temperature environment (60^{0}C)	Yes	Design criteria: 10^{0}C - 60^{0}C
Access to the inside of the PED	Yes	Access to the inside of the PCV via reactor standpipe or a Dia 270mm vertical penetration.
Investigation of the position/condition of fuel	Yes	Potential to grip & manipulate fuel or use in conjunction with CCTV camera / radiation detector.
Correspondence to the disclosure of technical information & remodeling	Yes	Potential to customize a standard machine to meet customer specific requirements.
Dispatch of operation engineers	Yes	Deployment of manipulator drivers to Fukushima Daiichi Nuclear Power Station is possible.

4. Technologies To Be Developed

ModuMan 25 may be fitted with a diverse suite of instrumentation (radiation detectors / CCTV cameras / temperature & humidity probes etc) to enable the characterization of fuel debris. This instrumentation is available for installation onto the manipulator by JFN.

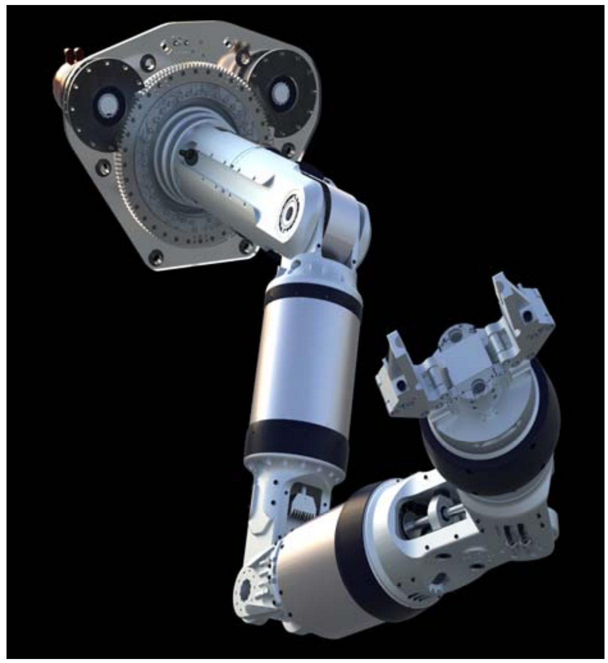
The manipulator may also be used to remotely recover debris samples for analysis. JFN has designed a suite of remotely operated sample recovery capsules.

5. Remarks

A light duty, highly dexterous, power manipulator designed to enable the remote deployment of measuring & sensing equipment, deployed from within its self contained enclosure, located on the reactor pile cap.

Technical Catalogue	
Classification	Working Mechanism
Title	Heavy Duty Hydraulic Manipulator (ModuMan 100)
Proponent	James Fisher Nuclear Ltd

1. Technical Details (features, specification & performance)



Key features comprise:

- 6 degrees of freedom
- Modular Design
- Radiation tolerant
- External, remote valve pack
- Hydraulic fluid options
- IP 68 rated
- Control system options
- Remote jaw exchange
- Dia 270mm deployment aperture

Standard System Configuration

Shoulder Rotate	+/-130°Rotary	Hydraulic Actuator / Motor options
Shoulder Pitch	+/-90°	Linear Hydraulic Actuators
Elbow Pitch	+/-130°Linear	Hydraulic Actuators
Wrist Pitch	+/-130°Linear	Hydraulic Actuators
Tool Rotate	continuous	Rotary Hydraulic Actuator
Jaws	150mm	Linear Hydraulic Actuator
Reach	2359mm	
Payload	100Kg	Throughout whole range of motion
Jaw Grip Force	2500N	
Tool Rotate Torque	250Nm	
Operating Fluid	Renolin PG32 / Water	
Operating Pressure	210 Bar	
Operating Modes:	Individual joint control Resolved tip motion Rate control Teach & repeat (Option) Collision Avoidance (Option)	

2. Past Application (including past applications at domestic plants, foreign plants, & in other industries)

Solid ILW waste retrieval & segregation operations at Sellafield Ltd UK.

3. Reasons to be considered as applicable to Fukushima Daiichi Nuclear Power Station, along with technical issues.

Applicable Use	Applicability	Remarks & Reasons
Usability in a radioactive environment	Yes	Radiation resistant specifications. Electronics mounted remote from the in cell arm.
Usability in a high temperature environment (60^0C)	Yes	Design criteria: 10^0C - 60^0C
Access to the inside of the PED	Yes	Access to the inside of the PCV via a vertical or horizontal Dia 270mm penetration.
Investigation of the position/condition of fuel	Yes	Potential to grip & manipulate fuel or use in conjunction with CCTV camera / radiation detector.
Correspondence to the disclosure of technical information & remodeling	Yes	Potential to customize a standard machine to meet customer specific requirements.
Dispatch of operation engineers	Yes	Deployment of manipulator drivers to Fukushima Daiichi Nuclear Power Station is possible.

4. Technologies To Be Developed

ModuMan 100 may be fitted with a diverse suite of instrumentation (radiation detectors / CCTV cameras / temperature & humidity probes etc) to enable the characterization of fuel debris. This instrumentation is available for installation onto the manipulator by JFN.

The manipulator may also be used to remotely recover debris samples for analysis. JFN has designed a suite of remotely operated sample recovery capsules.

5. Remarks

The modular design enables cost / time effective reconfiguration of the manipulator arm assembly to meet customer specific requirements.

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	**Control device and associated software**
Title	**Visual feedback control of robotic devices via overhead/external camera**
Proposed by	**Dr Max BLANCO**

1. Technical description (Advantage, Specification, Performance)

A control system or a data acquisition system from overhead or external cameras. System is known as `visual feedback control' or `visual servoing' of mobile robots. Applicable to both static and dynamic/mobile devices. Remote control via wireless wifi and/or Bluetooth technology.

SYSTEM IS FULLY SCALABLE : ROBOTS CAN NUMBER 1, 2, 4, 8, 16, 32, 64...

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

12 months in lab to develop the system. No industrial experience.

3. Applicability to Fukushima site, Technical challenges

We propose a control system only. Tests with prototype decontamination machinery might encounter hurdles.

Map creation is helped by the release of `as-built' drawings of TEPCO site.

http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/20120315_02.html

Deployment of multiple overhead cameras is essential to control of robots in TEPCO, at least to verify the state of TEPCO, if not to control the robots.

4. Technology Development (Example)

See appended figures.

5. Note

Requires full-scale off-site experimental facility in order to verify the system.

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Remote Visual Inspection and Machining
Title	Reactor Core Inspection – Consultancy
Proposed by	Atkins Energy (Nuclear)

1. Technical description (Advantage, Specification, Performance)

The information submitted below relates to our consultancy services. We offer to provide technical support relating to the inspection of the facilities: -

- Atkins has led the specification, design, manufacture, assessment and deployment of remotely operated visual inspection equipment, for the inspection of reactor core components within reactor pressure vessels (Advanced Gas-cooled Reactors).
- We have completed assessments of commercially available equipment for use in reactor, including radiation tolerance testing.
- We have designed and developed remotely operated retrieval equipment and drilling tools for use in reactor.

2. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

UK civil nuclear reactors.

3. Applicability to Fukushima site, Technical challenges

Our expertise is most applicable to Fukushima in assessing the inspection needs and carrying out a review of remote inspection equipment, identifying where there may be opportunities to utilise the existing technology. We will identify technology gaps and are able to work with suppliers to support the necessary developments that are needed in order to qualify the items for safe use. Our in-house expertise includes the development of manipulators to deliver inspection equipment to remote locations.

4. Technology Development (Example)

We have a number of technology developments to our name. These demonstrate our engineering capabilities and creativity in seeking applicable solutions to problems: -

- Development of a manipulator to deploy a videoscope into the reactor core.
- Development of a remote cutting tool to gain access within the reactor core.

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Remote Visual Inspection
Title	Underwater Inspection Consultancy
Proposed by	Atkins Energy (Oil and Gas)

6. Technical description (Advantage, Specification, Performance)

The information submitted below relates to our consultancy services. We offer to provide technical support relating to the inspection of the facilities: -

- Atkins are a leading, globally-based oil and gas subsea integrity management consultancy provider.
- We design integrity management programmes and review the inspection equipment capabilities of inspection equipment for the oil and gas industry.
- We represent major oil and gas companies on board vessels and platform installations, engaged in the supervision of inspection campaigns.
- We prepare reports of findings, presenting our views on the results of the inspections.

We also carry out technical assurance appraisals of equipment which is used in safety critical applications in the oil and gas industry (e.g. internally-installed high pressure isolation tools), providing clients with reviews and advice on critical areas which require additional development effort in order to meet project risk performance targets.

7. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Clients are confidential; all are large oil and gas companies. Representative projects we have been involved with include:

- Subsea infrastructure decommissioning inspection campaigns – UK North Sea
- Representation of oil and gas company clients on board subsea inspection vessels, utilizing a range of remotely controlled underwater inspection equipment – UK North Sea
- Technical assurance activities for the use of a high pressure isolation tool in a pipeline (Trinidad)

8. Applicability to Fukushima site, Technical challenges

Our expertise is most applicable to Fukushima in assessing the remote inspection needs and carrying out a market review of oil and gas industry subsea inspection equipment, identifying where there may be opportunities to utilize the existing technology. We will identify technology gaps and are able to work with suppliers to support the necessary developments that are needed

in order to qualify the items for safe use. Our in-house expertise includes Safety Engineering and Reliability Engineering (we can carry out FMECA assessments)
9. Technology Development (Example) We have a number of technology developments to our name. These demonstrate our engineering capabilities and creativity in seeking applicable solutions to problems: - • Development of industry-leading pipeline thermal buckling assessment tools • Novel subsea pipeline internal plastic lining technology
10. Note ----

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Remote-control operation machine
Title	Remotely operated mechanical handling systems
Proposed by	Atkins Energy (Nuclear)

11. Technical description (Advantage, Specification, Performance)

The points below relate to our consultancy and design services. We offer to provide technical support relating to the inspection of the facilities:-

- We are a leading globally based nuclear engineering consultancy. We provide a whole range of consultancy services, ranging from safety case authoring through to design of mechanical handling systems for operation in nuclear environments.
- We work closely with other leading global nuclear consultancies also offering the full range of services to existing nuclear installation operators as well as decommissioning services for legacy nuclear installations.
- We are able to provide design services for remotely operated mechanical handling systems, working closely with manufacturers to provide a full service to the client. We are also capable of providing technical assurance appraisals of equipment to be used in safety critical applications in nuclear operations. This technical appraisal includes providing reviews and advice on critical areas for further development in order to minimise risk.

12. Past experience (Plant in Japan, overseas plant, application in other industries, etc.)

Clients are confidential, however vast experience in design of large scale mechanical handling systems, many remotely operated for nuclear installations in the UK predominantly, but with additional experience outside the UK when combined with our international partners.

13. Applicability to Fukushima site, Technical challenges

Our expertise is most applicable to Fukushima in two areas.

- Assessing the inspection requirements and conducting market reviews of existing inspection equipment, providing advice on modifications or redesign required to fulfil the rigorous safety requirements of the nuclear industry regulations.
- Design of mechanical handling equipment, either locally or remotely operated, to fill gaps in existing technology. We work closely with suppliers to deliver designs for bespoke mechanical handling equipment to nuclear installations.

We also have a large range of expertise in Safety assessment that would also be useful in a more general sense.
14. Technology Development (Example) No specific technology developments, however many years of experience in the design of bespoke mechanical handling solutions for use in nuclear environments including nuclear rated lifting cranes and handling systems for nuclear waste products.
15. Note --

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	System Integration, Test, and Training Resource
Title	Integrated System Integration, Test, and Train Resource
Proposed by	Idaho National Laboratory

1. Technical description (Advantage, Specification, Performance)

The INL has an extensive history of developing and deploying specialized equipment, and instrumentation in support of nuclear reactors, decommissioning, and fuels. The INL has experienced personnel, proto-type facilities, and reactors for testing.

Examples: Developed and deployed equipment in support of TMI II. Developed and deployed equipment in support of nuclear facility closures.

Under water radiation hardened Non-Destructive Test/Evaluation of irradiated fuel inspection systems for fresh fuel, spent fuel, and storage canisters.

The Idaho National Laboratory has the capability to test materials at high gamma fields surrounding spent fuel in the ATR Canal and A Rabbit system for exposing materials to high neutron fields.

2. Past experience: Figure 1 TMI Core Topography System, Figure 2 Multi-Axis Ultrasonic Data Acquisition System.

3. Applicability to Fukushima site, Technical challenges

Experimental radiation testing of materials – ATR Reactor INL

Development of sensors and inspection equipment - INL

Development of sensors and inspection equipment and tested in a high radiation field – INL.

Figure 1

Figure 2

4. Note

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	3-D Core-Mapping Data Acquisition System
Title	Core-Topography Data Acquisition System
Proposed by	Idaho National Laboratory

1. Technical description (Advantage, Specification, Performance)

Advantage:

A critical problem in the defueling of Fukushima Daiichi Units 1-3 is the need to see what the damage is in side of the reactor vessels and storage pools.

The advantage of this technology is that it is proven technology that was deployed successfully at TMI II to provide a 3-Dimential image/model of the inside of the reactor vessel. See figure 1 and 2 below.

Specification:

This system provided data that was less than plus and minus 1 CM over the diameter of the TMI II core. (~3M)

Performance: see attached photo of 3-D model.

This system was developed at the INL to support Three Mile Island (TMI) reactor accident. The purpose of this system was to map the unknown damage in TMI Unit II reactor vessel. The data acquired provided a three dimensional image of the reactor internals indicating the location of the fuel debris after the loss of fluid and fuel meltdown. This data was most valuable assets used extensively during the vessel defueling process.

2. Applicability to Fukushima site, Technical challenges

Provide 3-Dimentional image of Fukushima damaged reactor cores and fuel storage pools.

Determine damage to fuel core and fuel storage pool.

3. Technology Development (Example)

An example of this technology is a system that was deployed at TMI II

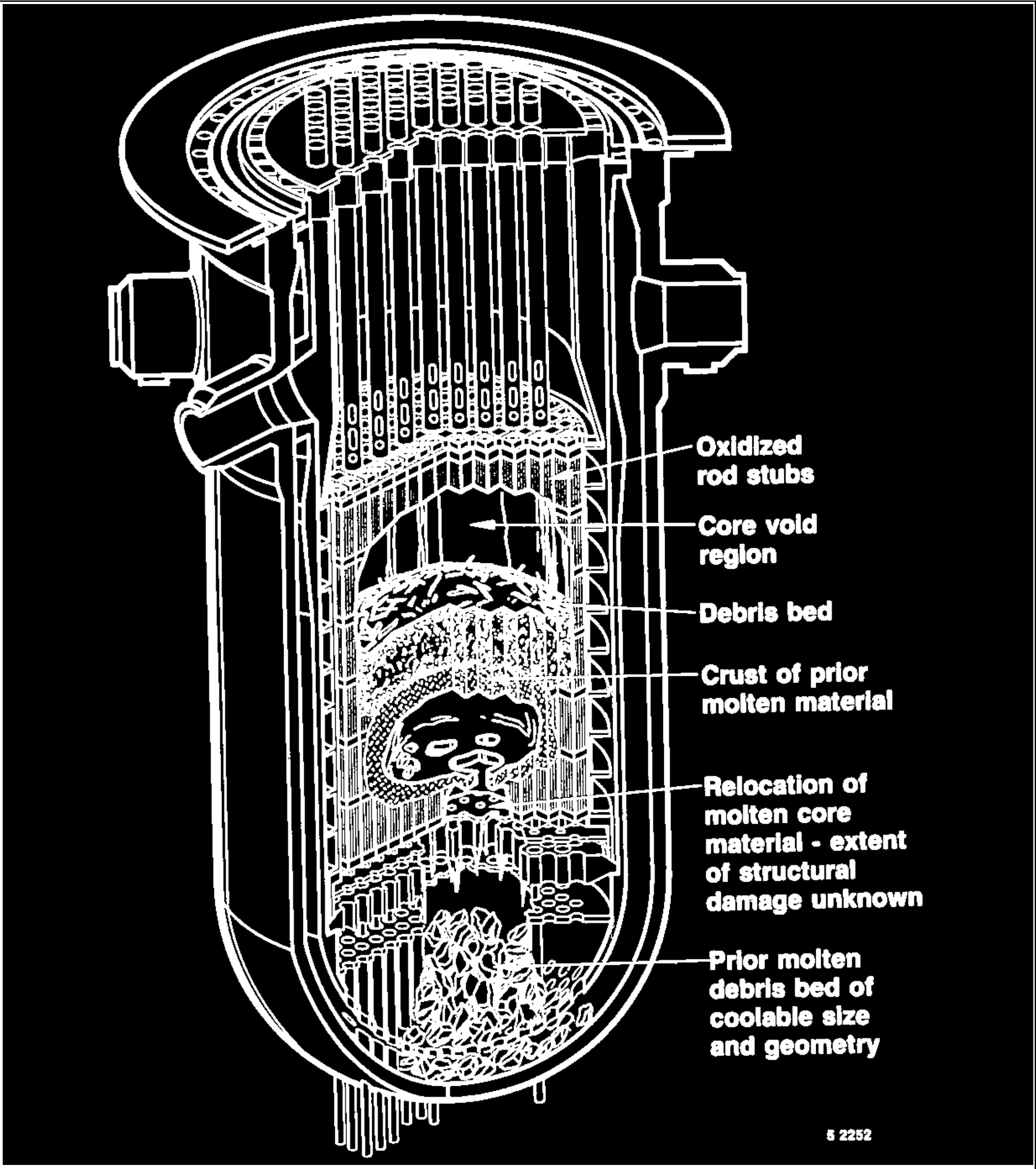


Figure 1. Visualization of TMI II core damage

Figure 2 Model of TMI II core damage

4. Note

Self-evaluation: This data was a most valuable assets used extensively during the vessel defueling process.
Note: (Price, Delivery, photo, etc.) Figure

[Format 2-3] Session2 Remote-control operation machine and measurement equipment for CV inspection

Technical Catalogue	
Mobile device classification	Leak Location Identification Technology
Title	Acoustic Water Flow Sensor System
Proposed by	Idaho National Laboratory

1. Technical description (Advantage, Specification, Performance)

The INL has an extensive history of developing and deploying specialized equipment, and instrumentation in support of nuclear reactors, decommissioning, and fuels. The INL has experienced personnel, proto-type facilities, and reactors for testing.

This system is proposed by the INL to triangulate the location of water leaks in the Reactor Pressure Vessel (RPV) and Pressure Containment Vessel (PVC). Sensors would be located to detect and monitor water flow.

2. Past experience: Locating underground radioactive drain pipe.

3. Applicability to Fukushima site, Technical challenges

This technology would be used to locate water leaks in both the Reactor Pressure Vessel and Pressure Containment Vessel.

4.