ABSTRACTS of the Technical Poster Session

第９回福島第一廃炉国際フォーラム

The 9th International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station

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NDF 原子力損害賠償・廃炉等支援機構
Nuclear Damage Compensation and Decommissioning Facilitation Corporation

Session A: Research and Development related to Decommissioning
廃炉関連研究開発全般

A01 Laser Technology for Decommissioning Nuclear Power

Yosuke Kawahito

原子力発電所の廃炉に向けたレーザ技術

川人 洋介，森 路子
国立研究開発法人 海洋研究開発機構

原子力発電所の廃炉は、施設の複雑さと危険性により、多くの技術的課題が存在する。特に解体作業においては、放射性廃棄物が大きな問題であり、その長期的な管理・保管のためには廃棄物量の減容化が重要となる。近年、廃炉作業における有望な技術としてレーザ技術が注目されている。本研究では、高出力レーザを用いて、放射性物質が付着したコンクリート表面に照射し、表面をガラス化することで放射性物質を閉じ込める手法を提案する。さらに、その後にガラス化した部分を切断除去することで、放射性廃棄物となるコンクリートの物量を効果的に削減することを目指す。これにより、廃炉に伴う安全性の向上と効率的な廃棄物処理の実現が期待される。

A02 Organizational Profile of IRID

Naoaki Okuzumi

技術研究組合 国際廃炉研究開発機構(IRID)の概要

奥住 直明，関 修，吉川 英樹
技術研究組合 国際廃炉研究開発機構

技術研究組合 国際廃炉研究開発機構(IRID)は、2013 年 8 月の設立以来、廃炉技術の基盤強化を視野に、当面の緊急課題である福島第一原子力発電所廃炉作業に必要な研究開発に取り組んできた。ここでは IRID の活動方針、福島第一原子力発電所の廃炉に関する役割分担、研究開発の取り組みについて紹介する。

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A04 Development of pipe inspection technology in high background radiation environment

Tatsuo Torii 1

高バックグラウンド放射線環境における配管内探査技術の開発

鳥居 建男 1, 林 高弘 2, 阪上 隆英 3, 黒澤 俊介 4, 小玉 翔平 5, 森下 祐樹 6
福井大学／福島大学 1, 大阪大学 2, 神戸大学 3, 東北大学 4, 埼玉大学 5, JAEA 6

配管内部観察で重要となる①水素含有量、②析出物の存在、③α線/β 線の放出核種の有無の 3 つのニーズに対応する技術を総合的に開発するため、既存の非破壊検査装置の小型化および非破壊で配管内部をイメージング可能な専用の放射線検出器の開発により、レーザ等を用いた非破壊検査により配管内の情報を取得するとともに、配管内の α 核種の有無や配管等の内部状況を明らかにすることを目的とした研究について報告する。

A05 Research and Development of the Project of Decommissioning, Contaminated Water and Treated Water Management and Connection to Engineering

Fumiya Sato

廃炉・汚染水処理水対策事業の研究開発及びエンジニアリングへの連携

佐藤 郁也, 角田 浩太
三菱総合研究所

福島第一原子力発電所の廃炉を安全かつ着実に進めるには、国内外の知見を結集した研究開発（R&D）が重要です。経済産業省は 2013 年度より、技術的難易度の高い R&D を公募型補助事業として支援する「廃炉・汚染水・処理水対策事業」を実施してきました。R&D は東電と連携し、現場適用性を評価しながら進められており、内部調査、燃料デブリの取り出し方法、作業環境の改善、固体廃棄物処理などに分類され、相互に連携しています。また、国内外から R&D に関する情報を収集するため、毎春に RFI（情報提供依頼）も実施されています。

A06 The Study on the Influence of Different Dose Rates on Damage to Lubricants at the Same Total Dose

Yoshikazu Hayashi

林 義和
㈱ MORESCO

世界最高峰の耐放射線性潤滑剤「モレスコハイラッド」は、原発、加速器や核融合等に世界で搭載され、廃炉でも試験的デブリ取出しアーム搭載を経て、今後の拡大取出しアームやその先端のデブリ切削/吸引の可変ツールでも評価が進む。我々はまた、潤滑剤(油やグリース)の放射線損傷を深く解析する学術研究も、国内外の主要学術機関と進め続けている。
今回は、量子研 QST と共同実施中の、モレスコハイラッド油を核としつつ一般的な鉱油や合成油ポリ α オレフィン(PAO)も交えた、放射線損傷に関する研究成果の一部を紹介する。
これはγ線での各油の耐性差を再検証するに留まらず、一定の被曝線量に至るまでの線量率の違いが及ぼす影響有無を世界初検証するもので、結果、線量率差は油損傷に差異を生じ、それに影響される物性も油の構造差によっても差異が生じる事、更にモレスコハイラッドは今回も鉱油や PAO を遥かに凌駕する秀逸な耐放射線性を示した。

A07 Research on physico-chemical behaviour of constitutional materials to understand the failure behaviour of pedestal concrete Second year progress

Go Igarashi 1, Aili Abudushalamu 2

ペデスタル部鉄筋コンクリート損傷挙動の把握に向けた構成材料の物理・化学的変質に関する研究 2年次進捗

五十嵐 豪 1, Aili Abudushalamu 1, 三浦 泰人 1, 丸山 一平 2, 宮本 慎太郎 3, 佐藤 拓未 4, 永江 勇二 4
名古屋大学 1, 東京大学 2, 東北大学 3, JAEA 4

本発表は, 令和5年度英知を結集した原子力科学技術・人材育成推進事業課題解決型廃炉研究プログラムの選定課題「ペデスタル部鉄筋コンクリート損傷挙動の把握に向けた構成材料の物理・化学的変質に関する研究」のプロジェクトの 2年次の進捗について説明する。

A08 Radiation-Hardened Serial Communication System with a Phase Adjustment Circuit

Utsuki Sekioka

位相調整回路を備えた耐放射線シリアル通信システム

関岡 空己, 渡邊 実, 渡邊 誠也
岡山大学

強放射線環境下では, 大規模集積回路(VLSI)に恒久故障が発生する. 宇宙システム用の耐放射線性 VLSI のトータルドーズ耐性は 10 kGy であるが, 1,000

Sv/h の放射線強度が予想される廃炉作業現場では，10 時間の寿命となる．廃炉作業用ロボットにはより高い放射線耐性が求められる．さらに，ロボットの制御とモニタリングには通信システムが必要である．そこで我々は DE1-SoC Field Programmable Gate Array（FPGA）上に三重化（TMR）設計を用いた耐放射線シリアル通信システムを開発している．通信回路と伝送線路に TMR 設計を適用することでトータルドーズ耐性を高めることができる．しかし，通信線路間で位相差が生じるため位相調整回路を提案する．

A09 Decommissioning research conducted by JAEA (4) Efforts regarding the disposal of radioactive wastes

Fumiya Nagao

JAEA が取り組む廃炉研究(4)放射性廃棄物の処分に関する取り組み

長尾 郁弥，大山 卓也，萩原 大樹，渡辺 勇輔，三本木 満，飯島 和毅
国立研究開発法人日本原子力研究開発機構

福島第一原子力発電所の廃炉工程で発生する様々な種類の固体の放射性廃棄物を安全に処分するために、現状では、発生する廃棄物の性状、廃棄体性状、想定される処分環境など、入力データに様々な不確実性が存在する中で、それらの不確実性を低減するとともに、そのような不確実性を前提とした安全評価を実施する必要がある。本発表では、現在原子力機構が処分の安全評価に関して実施している研究として、廃棄体や生活圏のパラメータ取得、処分概念の検討及び品質管理下の安全評価手法の検討に関する取り組みを紹介する。

A10 Operating temperature range of ring oscillator circuits for a radiation-hardened optically reconfigurable gate array

Shintaro TAKATSUKI

光再構成可能ゲートアレイへのリングオシレータの実装と温度特性評価

高月 信太朗，渡邊 実，渡邊 誠也
岡山大学大学院環境生命自然科学研究科

高放射線環境下で動作するロボットシステムには，放射線に対して高い耐性を持つ大規模集積回路（VLSI）が不可欠である．特に，順序回路の動作に必須のクロック信号を生成する水晶発振器は放射線に対して脆弱である．この課題に対し，我々は 1 Grad という極めて高い耐放射線性を有する光再構成可能ゲートアレイ（ORGA）上にリングオシレータを実装し，耐放射線性の高いクロック源として利用する手法を提案する.本研究では，このリングオシレータをクロック源として使用する手法の実用性を評価するため，温度特性に着目した．

A11 Evaluation of soft error tolerance on an optically reconfigurable gate array VLSI with a triple-modular redundant optical configuration circuit

Kiyoto Yonechi

3 重構成回路を持つ光再構成型ゲートアレイのソフトエラー耐性の検証

米地 巨豊，渡邊 実，渡邊 誠也
岡山大学

我々の研究室では光再構成型ゲートアレイを開発している．このデバイスは光によって回路情報を並列に送ることで，半導体の放射線による恒久的な故障を許容した運用を行える．既存の集積回路よりも約 1000 倍の放射線耐性を持ち，福島第一原子力発電所内の環境でも 1 年以上継続して運用できる．半導体デバイスでは一時的なエラー(ソフトエラー)も発生する．エラーが発生した場合は回路情報の上書きを行うことで訂正が行える．周期的に情報の訂正を行い，訂正速度が速いほどエラーの発生頻度を下げることができる．本研究では従来の光再構成型ゲートアレイより早く訂正が行える 3 重構成回路を実装し，ソフトエラーの耐性の向上を目指す．

A12 VTR design tool for an Optically Reconfigurable Gate Array

SOMA IMAI

VTR を用いた光再構成型ゲートアレイ設計ツール

今井 颯真
岡山大学

福島第一原子力発電所の廃炉作業では、ロボットを使用しなければならないがロボットに使用される集積回路は放射線に脆弱である。そこで本論文では、放射線に強い光再構成型ゲートアレイ用にカスタマイズされた Verilog-to-Routing(VTR)回路設計ツールの紹介を行う。

A13 1FRAME: 1F Fuel Retrieval and Monitoring Experiments

Mr. George Espy McKenzie 1, Mr. Doug Bowen 2, Ms. Angela Chambers 3, Ms. Daniela Henzlova 1, Mr. Akito Oizumi 1, Ms. Sophie Pignet 4, Mr. Jesson Hutchinson 1
Los Alamos National Laboratory 1, Oak Ridge National Laboratory 2, DOE – Nuclear Criticality Safety Program 3, Authority for Nuclear Safety and Radiation Protection 4

The 1FRAME (1F Fuel Retrieval and Monitoring Experiments) project includes collaborative research and development in the area of neutron detection, analysis, and simulations for fuel debris removal at Fukushima Daiichi nuclear power station. Technical advances are needed in all three focus areas to provide technical recommendations on a course of action for fuel debris removal. This work is part of collaborative research and development efforts between the US, Japan, and France.

A14 Laser Cutting Technology applied to Nuclear Dismantling Progresses made in FY24/25 towards wider deployment of technology fostered by mutual benefits of collaborative R&D

Mr. Julien GUILLEMIN, Mr. Damien ROULET
Onet Technologies K.K.

From the first use of laser cutting by ONET for the remote dismantling of a high-activity cell at CEA Marcoule site in France, through successful collaborative R&D projects, laser cutting has become a mature technology and a credible alternative to conventional cutting techniques. Laser cutting addresses complex nuclear decommissioning challenges, while respecting safety and radiation protection requirements.Several subsidized projects led by ONET have developed laser cutting technology for Fuel Debris Retrieval and safety countermeasures. In the latest development, demonstration of the existence of a solution to cut and remove CRDH was made.During a 4-years R&D project completed in 2024, funded by Euratom, ONET has demonstrated that in-air and underwater laser cutting is a safe and efficient technology for the dismantling of PWR and BWR Pressure Vessel Internals.In 2023, ONET has started operating its own facility called "LASER Technocenter". The facility is used to test laser systems before delivery to clients' sites, train future operators and keep increasing the performance of the technology.After benefiting from collaborative R&D, laser cutting is currently being deployed for reactor dismantling in France and has a high maturity to address complex remote cutting, with multiple applications to support Fukushima Daiichi Decommissioning.

A15 Increasing Efficiency of Nuclear Decommissioning with Virtual Site Access

Mr. Ehui Chong, Mr. Samuel Stephens
AtkinsRealis - Nuclear (UK)

AtkinsRéalis' Virtual Site Access is a cutting-edge service designed to support remote management of nuclear sites. Originally developed during the pandemic, it continues to deliver value by enabling secure, real-time access to site data via a cloud-hosted digital twin platform. Using technologies like LiDAR, drones, 360° cameras, and quadrupedal robotics, it captures high-resolution visual and spatial data to create a digital replica of the site.The service is structured around three core stages. In the Deploy phase, advanced tools such as LiDAR, drones, 360-degree cameras, and quadrupedal robotics are used to gather detailed visual data, offering greater insight than traditional point cloud or BIM models. During the Process phase, the collected spatial data is securely managed and can be desensitised to meet strict information assurance standards for cloud storage. In the Share phase, the data is made accessible remotely through secure cloud platforms, with support for immersive technologies like Extended Reality to enhance visualisation and collaboration.Virtual Site Access improves safety, reduces costs and carbon emissions, and enhances decision-making by minimizing the need for physical site visits?making it a vital tool for nuclear decommissioning

and infrastructure management.

Session B: Remote and Digital Technologies
遠隔・デジタル技術

B01 Application of remote strain measurement technology to decommissioning and its prospects

Akihiko Nishimura

遠隔歪計測技術の廃止措置への応用とその展望

西村 昭彦 1, 井出 次男 2, 石原 信之 2
日本原子力研究開発機構 1, 福井大学 2

JAEA からの技術移転により、我が国でもピコ秒レーザ加工による耐熱・耐放射線 FBG センサの安定供給が可能となった。現在、受注生産の体制でニーズに応えた仕様の FBG センサの供給が行える。今後の 1F 廃止措置、再処理プラント、次世代炉、核融合炉、などにおいては、据え付けに先立って FBG センサを設備や装置の要所に実装しておくことが望ましい。とりわけ燃料デブリ取り出しの遠隔操作機器について、その把持機構に FBG センサを実装しておくことで、燃料デブリ重量のその場計測が可能となる。これより遠隔歪計測が可能となることから保守保全の効果を高め、リスク低減を計ることが出来る。実施例と活用方法について報告と提案を行う。

B02 How digital simulation optimises decommissioning projects and waste-led strategies

Yuto Takae 1, Jean-Luc Flouttard 1

高江 勇斗 1, Flouttard Jean-Luc 1, Andrews Nicolas 1, Brunel Guillaume 2
Cyclife Digital Solutions 1, Cyclife Japan K.K. 2

Drawing on two use cases involving projects that use our simulation software, DEMplus® and FlexSim®, we will demonstrate how three-dimensional (3D) digital simulation tools are becoming an increasingly valuable resource for nuclear decommissioning activities, including scenario studies, the development of innovative remote technologies, detailed working methods, and waste management.

B03 Development of a Common Robot Network Platform Using RSNP

Nobuto Matsuhira

RSNP を用いた共通ロボットネットワークプラットフォームの開発

松日楽 信人 1, Young-woon Song 2, Kanzhong Yao 3, Christopher Bishop 3, Keir Groves 3, Simon Watson 3, 佐々木 毅 4, 山下 淳 1, 淺間 一 1
The University of Tokyo 1, Pohang University of Science and Technology (POSTECH) 2, The University of Manchester 3, Shibaura Institute of Technology 4

福島第一原子力発電所の廃炉作業では、燃料デブリの取り出しなど危険で高度な作業に対応するため、ロボット技術が導入されている。作業は長期にわたるため、共通性と標準化が重要であり、共通ロボットプラットフォームの構築が求められる。RSNP を用いることで、異なるロボットやセンサーのネットワーク化が可能となり、情報共有や協調動作が実現する。さらに、遠隔操作と自律移動を状況に応じて切り替えることで、狭隘空間でも安全かつ効率的な作業が可能となる。このプラットフォームは、将来的な拡張や保守作業の向上も目的としている。

B04 Development of an Integrated Management Support System for Nuclear Decommissioning

Mr. Samuel Thomas Stephens, Mr. Ehui Chong
AtkinsRealis

Complex decommissioning projects in high-hazard environments demand meticulous management and coordination across all aspects of delivery. These include design, manufacture and installation; personnel training; workforce management; and project and risk management. Digital solutions to support these functions are widely available, and opportunities are now emerging to integrate them?enhancing efficiency and reducing delivery risk.AtkinsRéalis has evaluated emerging technologies, delivery methodologies, and lessons learned from world renowned nuclear decommissioning projects. This led to the development of an integrated management software architecture designed to support the safe, effective, and efficient execution of decommissioning activities.The investigation focuses on four key functional areas, each informed by insights from industry subject matter experts and AtkinsRéalis' deep understanding of commercial off-the-shelf (COTS) technologies currently deployed at nuclear facilities and decommissioning sites worldwide. These core components include:? Engineering and Information Management? Project and Program Management? Workforce Management? Asset Operations and ManagementTo support implementation, AtkinsRéalis developed a digital transformation roadmap based on best practices in digital engineering for asset management and project execution?both within the nuclear sector and across other large-scale infrastructure environments. A well-architected, integrated management system can streamline operations, enhance data integrity, and strengthen compliance oversight.

B05 3D Point Cloud Data Acquisition Technologies for Radiation Mapping and Environmental Assessment

Ms. Daphne OGAWA 2, Mr. Yuichi Okamura 1, Mr. Victor Guillon 2

Tokyo Power Technology 1, Orano 2

This work presents a practical approach to radiation and structural mapping in areas that are difficult or unsafe for human access. By combining three complementary tools?MANUELA?, the FARO Focus Premium LIDAR, and the autonomous SPOT robot?accurate 3D models of radioactive environments can be generated to support decommissioning activities while reducing worker exposure and ensuring work safety.

Session C: Fuel Debris Properties and Analysis / Fuel Debris Tranfer and Storage

燃料デブリ性状分析、移送・保管

C01 Study on volatile Cs compounds interaction with structural steel and metallic debris during the 1F accident

Anton Pshenichnikov

福島第一原子力発電所事故における揮発性セシウム化合物と構造材および金属デブリとの相互作用に関する研究

プシェニチニコフ アントン, 多木 寛, ズベヒナ ベラ, ファム ヴ ハイ
国立研究開発法人日本原子力研究開発機構

福島第一原子力発電所内部における放射性セシウム(Cs)の状況解明は、安全な廃炉作業の鍵となる。本研究では、事故環境を模擬した条件下で、CsOH とステンレス鋼および金属デブリとの相互作用を調査し、事故時の Cs 挙動を評価した。実験結果から、500～1000℃において、CsOH が予備酸化されたステンレス鋼や金属デブリと反応し、表面に Cs₂CrO₄ や Cs₂MoO₄といった新たな化合物が生成されることが確認され、熱力学解析からも支持された。また、酸化層内部への Cs 浸透も観察された。本研究は、汚染除去方法の策定に資する重要な知見を提供した。今後は詳細な分析データを用いて、事故時の温度分布推定や debrisEye マップへの統合を目指す。

C02 An Example of Thermodynamic Approach to 1F Accident Phenomena: JAEA/CLADS Contributions to TCOFF and TAF-ID

Hiroshi Ohgi

1F 事故現象への熱力学的アプローチの例：TCOFF および TAF-ID への JAEA/CLADS の貢献

多木 寛
国立研究開発法人日本原子力研究開発機構

福島第一原子力発電所(1F)1 号機ペデスタルの内部調査で、コンクリートの崩落と鉄筋の露出が確認された。これは、溶融炉心コンクリート反応(MCCI)や低温条件下でのコンクリート融解の可能性を示唆している。OECD/NEA のプロジェクトにて開発されている TAF-ID データベースを用いた予備的な熱力学的評価では、SiO₂を主成分とするコンクリートの融解温度は約 1050-1100° C と推定された。現在、詳細な模擬コンクリート溶融試験により、データベースの妥当性検証を進めている。

C03 Estimation of status inside the PCV in unit 2 using results of analysis of samples from trial fuel debris retrievals

Masato Mizokami 1

試験的取り出し燃料デブリ分析結果を用いた PCV 内の状態推定

溝上 暢人 1, 平井 睦 1, 溝上 伸也 1 2, 池内 宏知 2
東京電力ホールディングス株式会社 1, 国立研究開発法人日本原子力研究開発機構 2

福島第一原子力発電所 2 号機では、燃料デブリの試験的取り出しを 2 回実施している。採取箇所の情報や、燃料デブリ分析結果をもとに格納容器内の状況推定を行った。

C04 Current Status of Analysis of Fuel Debris Obtained from the First Trial Retrieval at Fukushima Daiichi Nuclear Power Station Unit 2

Hirotomo Ikeuchi 1,

池内 宏知 1, 荻野 英樹 1, 前田 宏治 1, 北垣 徹 1, 小畠 雅明 1, 小林 徹 1, 溝上 暢人 2, 溝上 伸也 2
日本原子力研究開発機構 1, 東京電力ホールディングス株式会社 2

To proceed the decommissioning of Fukushima Daiichi Nuclear Power Station (FDNPS), analysis of the fuel debris obtained from the trial retrieval at Unit 2 is underway to characterize their properties. This presentation will report key findings from various analyses, including non-destructive analysis, solid analysis, and solution analysis.

C05 Preliminary application of MIK1.0 code for Supercritical Kinetic Analysis of Pure UO2 Particles Falling into Water

Ms. Thi Dung Nguyen 1, Mr. Hiroki Takezawa 1, Mr. Jun Nishiyama 2, Mr. Liem Peng Hong 3, Mr. Toru Obara 4, Ms. Yoko Yoshimura 5
Nagaoka University of Technology 1, Tokyo City University 2, NAIS 3, Institute of Science Tokyo 4, NDF 5

This study preliminarily integrated the Multi-region Integral Kinetic code MIK1.0

with geometry updates from the Moving Particle Semi-implicit (MPS) simulation for the supercritical kinetics of pure UO2 particles falling into water. Fission reaction rate was calculated considering time-dependent particle distributions.

Session D: Internal Investigation and Fuel Debris Retrieval Technologies
内部調査 / 燃料デブリ取り出し技術

D01 The World's Highest Radiation Tolerant Performance Camera

Shigemasa Oga

世界の原子力施設で活躍する耐放射線性カメラシステム

大賀 成将, 大西空
コーンズ テクノロジー株式会社

コーンズテクノロジー株式会社は、原子力施設や研究所に耐放射線性カメラを供給する英国 Mirion Technologies (IST)社の国内代理店です。Mirion 社は 40 年近くにわたり耐放射線性カメラの供給と技術開発を続けており、原子力施設内の監視用途（CCTV）や炉内調査・メンテナンス、ロボットやアーム装置の操作や監視等、世界中の原子力施設で幅広く活躍する耐放射線性カメラをご提供しております。最近では CMOS 技術を採用した高い耐放射線性（1MGy 対応）を持つカラーシステムカメラも開発され、線量が高く厳しい環境下でもカラー映像の取得が可能になりました。小型軽量のカラーカメラやパンチルト機構や照明オプションを持つシステムカメラ等、ユーザ様のご要望を満足する幅広いカメララインナップをご紹介しております。

D02 Preliminary Calculation of Voxel keff for Fuel Debris Particles

Anna Ohgaki 1, Takezawa Hiroki 1, Nishiyama Jun 2

燃料デブリ多粒子体系を対象としたボクセル keff に係る検討

大垣 杏奈 1, Takezawa Hiroki 1, Nishiyama Jun 2
Nagaoka University of Technology 1, Tokyo City University 2

Session E: Spent Fuel Removal
使用済み燃料取り出し

E01 Contributing to Fukushima reconstruction through the manufacture of decommissioning-related products.

Tomokazu Harada

「廃炉関連製品の製造を通じた福島復興への貢献」

原田 友和
東双みらい製造株式会社

当社は、福島第一・福島第二原子力発電所の廃炉作業において利用される金属キャスクや燃料デブリ保管容器等の製造を通じて、浜通り地域をはじめとする福島県全域の復興に貢献したいとの思いから、東京電力ホールディングス株式会社およびカナデビア株式会社(旧日立造船)により 2022 年 10 月に共同で設立されました。 現在、地元企業と工場建設の準備工事を進めるとともに、本格製造に向けたサプライチェーン構築を進めています。 原子力関連製品を、地元企業と密接に連携し製造することで、廃炉の推進、経済発展、雇用創出、人材育成等に貢献してまいります。

E02 Construction status of large cover for fuel removal from Fukushima Daiichi Nuclear Power Station Unit 1 and removal of existing damaged steel frames using remote-controlled machine

katsunori enomoto 1

福島第一原子力発電所 1 号機の燃料取り出し用大型カバーの建設状況と遠隔操作装置を用いた既存損傷鉄骨の撤去

榎本 勝則 1, 野田 浩 1, 細川 将人 1, 赤丸 賢一 1, 木部 直人 1, 豊島 憲治 2, 平田 明生 2, 宮崎 美穂 2, 松尾 一平 2, 西岡 聖雅 2, 水谷 亮太 2
東京電力ホールディングス株式会社 1, 鹿島建設株式会社 2

福島第一原子力発電所1号機は原子炉建屋上部に燃料取り出しのための大型カバーを建設し, その中で遠隔で燃料を取り出す計画である。大型カバー設置工事のうち上部架構の設置はほぼ完了しており, ボックスリングの設置に着手している。また、損傷した原子炉建屋の外周鉄骨がカバー内に設置する遮蔽体と干渉しているため, 作業員の被ばく線量を低減できる遠隔操作装置を使用して撤去作業を行った。

E03 Construction status of platform structure for spent fuel removal from Fukushima Daiichi Nuclear Power Station Unit 2 and installation method of runway girder with reduction radiation exposure

katsunori enomoto 1,

福島第一原子力発電所 2 号機の使用済燃料取り出し用南側構台の建設状況と被ばく線量低減を考慮したランウェイガーダの設置方法撤去

榎本 勝則 1, 野田 浩 1, 中村 竜也 1, 齋藤 剛 1, 清水 一希 1, 谷山 元祥 2, 中越 淳郎 2, 宮崎 美穂 2, 松尾 一平 2, 小川 喜平 2
東京電力ホールディングス株式会社 1, 鹿島建設株式会社 2

福島第一原子力発電所2号機は原子炉建屋南側に燃料取り出し用構台を建設し，原子炉建屋南側外壁に開口を設け，ランウェイガーダを原子炉建屋内に侵入させて，使用済燃料を取出す計画である。燃料取り出し用構台の建設とランウェイガーダの設置は完了し，現在は燃料取扱設備の設置作業が行われている。尚、原子炉建屋内は非常に高線量のため，ランウェイガーダは燃料取り出し用構台側から送り出し工法により設置した。

Session F: Radiation Measurement Technologies and Radiation Durability
放射線計測技術と放射線耐性

F01 Development of fiber-type dadiation monitor with red or infrared scintillation materials ver.2025

Shunsuke KUROSAWA

赤色・近赤外発光シンチレータを用いたファイバータイプの線量計の現状（2025）

黒澤 俊介，浦野 雄介，藤原 千隼，山路 晃広
東北大学

光ファイバーと赤色・近赤外発光シンチレータを用いた数 Sv/h 以上の高線量率場で測定できる線量計の現状について報告する。

F02 Research on omnidirectional neutron imaging system for ensuring safety in debris removal

Nishiki Matsubayashi 1

デブリ取り出しの安全性確保を目的とした全方位型中性子イメージング手法の研究

松林 錦 1，鳥居 建男 2，眞田 幸尚 3，黒澤 俊介 4，佐々木 美雪 3
京都大学 1，福島大学 2，日本原子力研究開発機構 3，東北大学 4

本研究では、1F の廃炉作業を安全に行うため、燃料デブリ取り出し作業時に発生した中性子の方向特定を目的として、小型軽量な全方位型中性子イメージング手法を開発する。これまで開発されたΒ・Γ線イメージャーであるFRIE（Fractal Radiation Imaging Elements）検出器を応用し、中性子の飛来方向を検知できる新たな検出器の設計を行った。検出器は、正四面体のアクリルに薄い中性子用シンチレータを貼り付け、遮蔽材とフラクタル構造を組むことにより、中性子に対して方向依存性を有する。概念設計した検出器においてモンテカルロ計算コードを用いて応答特性を評価した、また検出素子の照射試験を行い中性子／Γ線弁別性能を評価した。

F03 Evaluation of compliance with regulatory standards in decommissioning work using ETCC quantitative gamma ray imaging

Toru Tanimori 2, Tadashi Yoshida 1

ETCC の定量的ガンマ線イメージングによる廃炉作業での法令基準適否の評価

谷森 達 2, 吉田 正 1, 高田 淳史 1
エルライ株式会社 1, 北里大学未来工学部 2

ETCC は γ 線毎に方向を決定し光学カメラと同原理で撮像。輝度測定ができ、面や空間 γ 線の放射能(counts/sec/cm2/sr/keV)を画像内の点に表示可。コンプトン方程式を満たす γ 線のみを使い連続 γ 線のスペクトル撮像可。福島 1F では 1〜3 号炉を含む広域の 0.1-3MeV 撮像で百点以上のスペクトルを同時に得、スカイシャインスペクトル、ステレオ法で全域の 3 次元線量撮像に成功。京大原子炉では41Arプルーム3次元撮像に成功。文科省英知事業に2度採択(2018、2022)、上記成果を得た。30m離れ位置精度 30 ㎝、広がり誤差 1m。外部から建屋内 γ 線の CT スキャン、10m平方の壁面百か所を同時にスペクトル測定可。ETCC は廃炉作業で法令基準の適否判断に利用可能

F04 Triple modular redundant RISC-V processor and test circuit for radiation test

masato isobe

三重化 RISC-V プロセッサと放射線試験用のテスト回路

磯邉 雅人, 渡邊 実, 渡邊 誠也
岡山大学大学院環境生命自然科学研究科

現在福島第一原子力発電所の廃炉環境は 1000Sv/h という非常に過酷な放射線環境が想定されており, ロボットを用いる必要がある. しかし宇宙環境で使用されるような, 一般的に放射線耐性があるといわれているプロセッサでさえおよそ 10 時間程度で故障してしまう. また, 二次被ばくやコストの観点からも, 故障個所の交換を行うことによる対応は現実的ではない. そこで我々は放射線による故障を許容して運用可能なプロセッサの開発を行っている. 本稿では, 故障を許容して運用可能な三重化 RISC-V プロセッサの開発実装と, 4 キロベクレルのアメリシウムを使用したα線源の放射線試験用のテスト回路について述べる.

F05 Operating area evaluation of optically reconfigurable gate array VLSI that can be fully parallel configured

Ryosuke Ogawa

完全並列構成が可能な光再構成型ゲートアレイ VLSI の動作領域評価

小川 綾介，渡邊 実，渡邊 誠也
岡山大学大学院環境生命自然科学研究科

原子力発電所や宇宙のような高放射線環境下では半導体素子が劣化し，集積回路に恒久的な故障を引き起こす。このような環境で集積回路を長時間動作させるためにハードウェア的に故障した部分を回避して回路を再構成することを可能にしたプログラマブルデバイスである光再構成型ゲートアレイ VLSI がある。また，構成回路の D-FF を取り除いてさらに耐放射線性を高めた完全並列構成が可能な光再構成型ゲートアレイ VLSI の動作可能なレーザの光パワーとトランジスタのゲートに与える中間電圧の範囲についての評価を行い，結果を報告する。

F06 Evaluation of soft error tolerance by implementing Quintuple Modular Redundancy

Shuto Shiba

5重回路実装のソフトエラー耐性の評価

柴 修斗，渡邊 実，渡邊 誠也
岡山大学 渡邊研究室

我々の研究室では光再構成型ゲートアレイ(ORGA)の開発を行っている．光による並列的なプログラムのため，SRAM 型 FPGA よりも回路故障が起こりにくく，構成メモリのソフトエラー耐性が高い．しかし，ゲートアレイ VLSI 上の回路にもソフトエラー耐性が必用である．このソフトエラー対策の一つとして三重回路(TMR)が実装された．これにより1つのモジュールにソフトエラーが発生しても，残り2つの演算結果により正しい出力を得られるため，デバイスの信頼性の向上に役立つ．本研究ではさらなる信頼性の向上のため，三十回路から2つ回路を増やした五重回路のソフトエラー耐性について評価した．

F07 Evaluation of Neutron Detection Technology and Analysis Techniques to Support Fukushima Daiichi Decommissioning

Ms. Daniela Constance Henzlova, Ms. Natalie Cannon, Mr. Jesson Hutchinson, Mr. George McKenzie, Mr. Jawad Moussa, Mr. Mark Nelson, Mr. Robert Weldon
Los Alamos National Laboratory

Decommissioning efforts and associated fuel debris retrieval from the damaged Fukushima Daiichi reactor units require robust methods to monitor and assure subcriticality. These include adequate detection technologies capable to withstand high gamma radiation conditions within the units; as well as analysis methods capable to provide robust signatures to assure agile criticality monitoring in situation where material distribution is changing. This poster will present experimental and analytical efforts focused on evaluation of neutron-based technologies and development of real-time analysis using state-of-the art capabilities available within the 1F Fuel Retrieval and Monitoring Experiments

(1FRAME) project.

Session G: Investigation of Integrity
健全性確認

該当なし（N/A）

Session H: Radioactive Waste Management
廃棄物対策

H01　SIAL® : Geopolymer solidification technology approved by Slovak / Czech Nuclear Authority

Hisashi Mikami 1

SIAL® : スロバキア、チェコにおいて認可されたジオポリマー固型化技術

見上 寿 1, 関根 伸行 1, 平田 一尭 1, Marcela Blazsekova 2, Milena Prazska 2, Maros Juraska 2, Marek Meciar 2
富士電機株式会社 1, Amentum Slovakia s.r.o. 2

スロバキアとチェコの規制当局から認可されている SIAL® ジオポリマー固型化技術の特徴と性能の実績を紹介します。この技術は約20年に亘り運用されています。近年、ジオポリマーは、温暖化ガス削減に効果のある固型化剤であるとともに、核種閉じ込め性能や耐熱・耐酸性能に着目され、セメントでは固型化困難な廃棄物への適用が EU PREDIS Pj 等で検討されています。この特性は、福島第一原子力発電所の汚染水二次廃棄物に対しても、スラッジや各種スラリー等の模擬廃棄物固型化試験で示されています。最近では、デブリ取り出しに際し、炉内のデブリの安定化のため、残存炉内構造物への圧送・充填性や PCV 底部止水等の検討を実施しています。

H02　Decommissioning research conducted by JAEA (3) Radioactive waste management initiatives

mitsuru sambongi

JAEA が取り組む廃炉研究 (3) 放射性廃棄物管理に関する取り組み

三本木 満, 伊藤 あずさ, 駒 義和, 大杉 武史, 岡田 尚, 飯島 和毅
国立研究開発法人日本原子力研究開発機構

福島第一原子力発電所（以下「1F」という）廃炉に伴い発生する固体廃棄物は、多種多様な性状を有する廃棄物が大量に存在しており、廃炉作業を進める上で，これらの固体廃棄物を安全かつ合理的に保管・管理および処理・処分することが重要な課題である。このため、JAEA では、1F 固体廃棄物の性状把握、保管、処理及び処分の各分野が連携をとり、必要な技術開発に取り組んでいる。本稿では、

1F 固体廃棄物に係る性状把握、保管、処理及び処分の各分野の研究開発に係る連携の紹介とともに、研究開発の一例として、保管分野の研究開発の取り組み状況について紹介する。

H03 Design and On-site Decommissioning Support to the Bohunice Nuclear Power Plant, Slovakia

Mr. John David Maddison, Ms. Nicole Cain
Amentum / Waste Management

Amentum (as Jacobs) have provided extensive waste management and decommissioning support to the Bohunice Nuclear Power Plant (NPP) in Slovakia for the first ever dismantling of a VVER-440 nuclear reactor. The work involving multiple phases has included the underwater dismantling and segmentation of reactor coolant system components, the design and provision of measuring equipment for radiological characterisation, and the delivery of a bespoke waste packaging and transportation system. Amentum are opening an office in Futaba to bring this type of experience directly to the Fukushima decommissioning challenges.

H04 Radioactive Scrap Metal Recycle, Japanese Demonstration

Colin Austin 2, Tomoaki Fujikawa 1

Colin Austin 2, 藤川 智章 1, 菊池 誠 2
丸紅米国会社 1, EnergySolutions 2

Energy Solutions (ES), with its rich experience in D&D, is now re-illustrating the international business strategy to design D&D around recycling, not just with the metals, but also with assets such as radio nuclides that can be harvested to be re-used as radioisotopes. Marubeni Utility Services (MUS), as ES's agent for the metals melt business, believes that this is going to be a paradigm shift for the D&D to become recycle projects, nota waste management project, and is very excited to work together through this phase to establish a new standard for Japan and the world.

H05 Transformational Technology Driving the Paradigm Shift From Nuclear Waste Disposal to Valuable Resource Recycling

Colin Austin 2, Tomoaki Fujikawa 1

Colin Austin 2, 藤川 智章 1, Milner Tim 1, 菊池 誠 2
丸紅米国会社 1, EnergySolutions 2

Energy Solutions (ES) is creating new value to nuclear wastes. This preserves important disposal site capacity via diversion and resource recovery and reduces carbon foot print by repurposing and reusing metals avoiding the greenhouse gas emissions from metal processing and steel manufacture. Additionally, providing a

source of radionuclides harvested for beneficial use from waste, to drive forward, radio-medicine, instrumentation, space flight and agriculture. This paradigm shift from waste to resource will enhance the vital role the nuclear industry will play in a sustainable energy future.

Session I: Decontamination and reduction of radioactive exposure
除染、被ばく低減

I01 3D Visualization of air-dose rate of working spaces by Digital Twin

Kenji Koizumi

デジタルツインによる作業環境線量率の 3D 可視化

小泉 健治, 鈴木 政浩, 青木 和久, 山田 進, 金 敏植, 鈴木 健太, 阿部 文明, 町田 昌彦, 岡本 孝司
日本原子力研究開発機構

1F 廃炉では原子炉建屋内の作業空間環境の改善が重要であり、先進的ツールを活用し、作業員の被ばくをできるだけ減らすことが最も重要な課題の一つである。JAEA では空間線量率の 3 次元分布を推定するデジタルソフトウェアツールを開発してきた。本ツールシステムでは、LASSO と呼ばれる機械学習手法を用い、限られた現場情報から放射線源の空間分布とその大きさを逆推定することが核部分となっている。遠隔操作ロボットに搭載した測定装置で測定した点群や空間線量率データから推定した汚染の 3 次元分布を表示するとともに、デジタル空間上で作業員の被ばく低減のための除染評価や安全性解析を行うことができる。

I02 Decontamination and Decommissioning Technologies for the Civil Nuclear Industry

Ms. Sarah Alexandra Peirce, Ms. Nicole Cain
Innovative Physics

The nuclear industry faces numerous challenges in decommissioning, including improving efficiency and safety while reducing costs. Advanced technologies, including robotics, sensors and artificial intelligence, have the potential to address these challenges by automating hazardous tasks, improving accuracy and reducing human error.

Session J: Others
その他

J01 WM2026

KAZUHIRO SUZUKI

The Annual Phoenix, AZ Conference

鈴木 一弘，三井 崇，小荒井 克典，岡田 聡，西澤 真理子
WM Symposia, Inc.

アリゾナ州フェニックス市において、毎年 3 月上旬に、世界中から 3,000 名を超える参加者を得て開催されている WM 国際会議は、米国アリゾナ州の NPO の WM Symposia, Inc.（WMS）により実施されています。WM 国際会議では、放射性物質とそれに関連するタイムリーな原子力バックエンドの問題に焦点を当て続けてきており、2013 年からは、毎年、福島第一の廃炉に関する特別セッションを設けています。WMS は、次世代の放射性廃棄物の専門家を育成するための教育とメンタリングの重要性を信じ、WM 国際会議からの資金を活用し、これまでに 600 万ドル（約 9 億円）の教育支援を行ってきています。

J02 Decommissioning research conducted by JAEA (2) Virtual reality comes to debrisEye a new step for decommissioning Support

Kenta Shimomura 1

JAEA が取り組む廃炉研究 (2) debrisEye における VR 導入−廃炉支援に向けた新たな展開−

下村 健太 1，山下 拓哉 1，永井 英一 2
Japan Atomic Energy Agency (JAEA) 1, Prometech Software, Inc. 2

福島第一原子力発電所（1F）の複雑な内部状況を理解するには、個別のデータだけでは限界がある。JAEA では、調査・解析結果を 3 次元モデル上に統合表示する可視化ツール「debrisEye」を開発し、空間的な把握の支援を進めてきた。本研究では、debrisEye に仮想現実（VR）技術を組み合わせることで、より没入的かつ直感的な体験を実現した。ユーザーの動きに応じた動的なライティング効果などにより、1F 構内の空間理解が一層深まり、今後の廃炉計画の立案・最適化に資する新たな支援手段としての展開が期待される。

J03 Golden Safety Rules: Orano’s experience in enhancing risk management on nuclear worksites

Ms. Daphne Ogawa Peirce, Mr. Bruno Conseil, Mr. Francois Delcroix, Mr. Thierry Deshogues
Orano

Orano’s “Golden Safety Rules” promote a fair management approach to enhance safety on nuclear worksites. Immediate work stoppage and structured post-hoc incident reviews address unsafe behaviors. This presentation explores how this system could support dismantling projects in Japan, with insights from La Hague

NCPF project, tackling challenges like degraded facilities in nuclear operation and complex multi-contractor environments.

A01 Laser Technology for Decommissioning Nuclear Power Plants

Yosuke Kawahito[1] and Michiko Mori[1]
[1]Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Abstract

Decommissioning nuclear power plants involves many technical challenges due to complexity and hazards. Radioactive waste is a major issue, requiring volume reduction for long-term management. This study proposes using high-power lasers to vitrify contaminated concrete surfaces, encapsulate radioactive materials, and then remove the vitrified layer to reduce waste volume and enhance safety and efficiency.

1. Introduction

The decommissioning of nuclear power plants presents numerous technical challenges due to the complexity and hazardous nature of the facilities. In particular, the generation of radioactive waste during dismantling is a significant issue, and reducing the volume of such waste is essential for its long-term management and storage. In recent years, laser technology has attracted attention as a promising solution for decommissioning work.

2. Research achievements

2-1. Vitrification of radioactive waste simulants

Figure 1 shows that a laser-based in-situ immobilization technique successfully trapped cesium (Cs) within concrete by forming a stable glass matrix. This method achieved a cesium capture rate of 99%, significantly higher than the 57% achieved by conventional plasma melting. The cesium leaching rate was also reduced to 0.06–0.08 g/m², well below the ASTM international threshold of 2 g/m², enabling safer and more reliable immobilization of radioactive cesium [1].

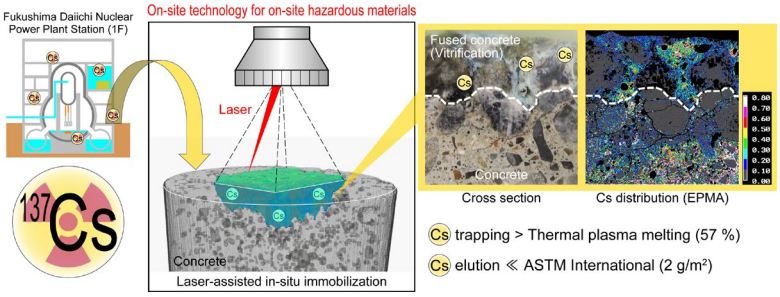


Figure 1. Vitrification of radioactive waste simulants

2-2. Laser cutting of a 1-meter reinforced concrete segment

We have developed a novel cutting method for reinforced concrete using an ultra-high-power laser without assist gas. This technology successfully achieved full penetration of a 1-meter-long reinforced concrete section with a 50-kW laser output [2].

3. Conclusion

This developed technology provides a practical solution for safely and efficiently handling radioactive hazardous materials on-site during the decommissioning of nuclear power plants.

References

[1] Materials & Design 252 (2025) 113766.

[2] Optics and Lasers in Engineering 180 (2024) 108258.

A02

Organizational Profile of IRID

Naoaki Okuzumi, Osamu Seki, Hideki Yoshikawa
International Research Institute for Nuclear Decommissioning (IRID)

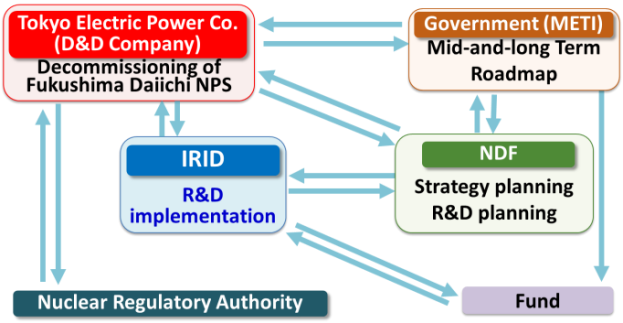
Abstract

Ever since the International Research Institute for Nuclear Decommissioning (IRID) was establishment in August 2013, IRID has engaged in research and development (R&D) of technologies necessary for the decommissioning of the Fukushima Daiichi Nuclear Power Station (NPS) which is an urgent issue. IRID focuses on strengthening the platform of decommissioning technology.

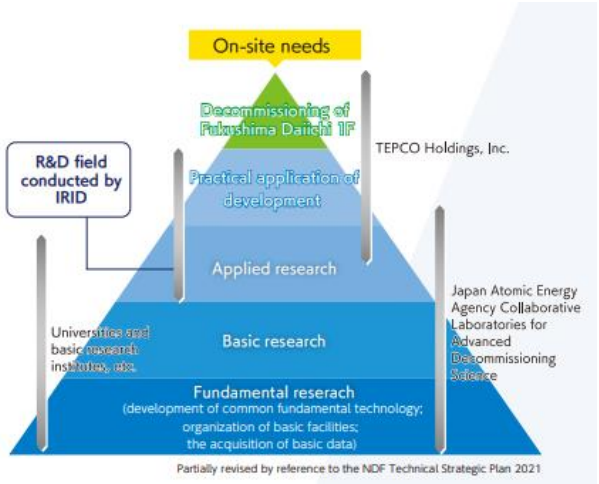
1. Scope of Work

- R&D for nuclear decommissioning
- Promotion of cooperation on nuclear decommissioning with relevant international and domestic organizations
- Human resource development for R&D

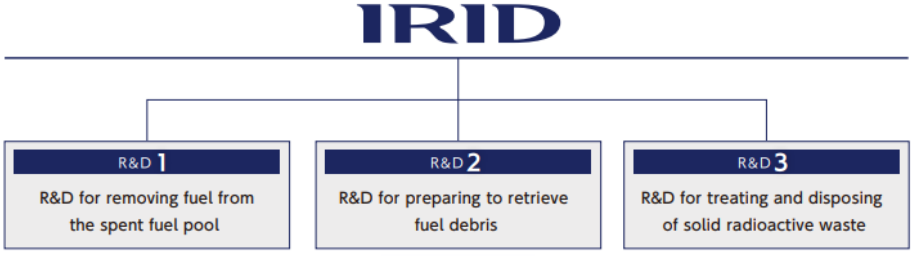
2. Roles of Organizations in the Decommissioning Projects of the Fukushima Daiichi NPS.



3. R&D Scope of IRID



4. Three major R&D for Nuclear Decommissioning



A03

Overview of IRID R&D Projects

Naoaki Okuzumi, Osamu Seki, Hideki Yoshikawa
International Research Institute for Nuclear Decommissioning (IRID),

Abstract

For the decommissioning of the Fukushima Daiichi Nuclear Power Station (NPS), four key players including TEPCO, the Japanese government, NDF and IRID are closely working together. IRID is a complex entity consisted of nineteen organizations that have responsibility in research and development (R&D) for the decommissioning of the Fukushima Daiichi NPS. IRID engages in three major R&D projects: (1) Project of fuel removal from spent fuel pool, (2) Project of preparation for retrieving fuel debris and (3) Project of the treatment and disposal of solid radioactive waste. These R&D projects are being conducted under the Mid-and-Long-Term Roadmap issued by the government. The period until completion of the decommissioning is divided into three phases. Currently, the third phase, R&D for preparation for retrieving fuel debris is underway.

1. Progress of R&D

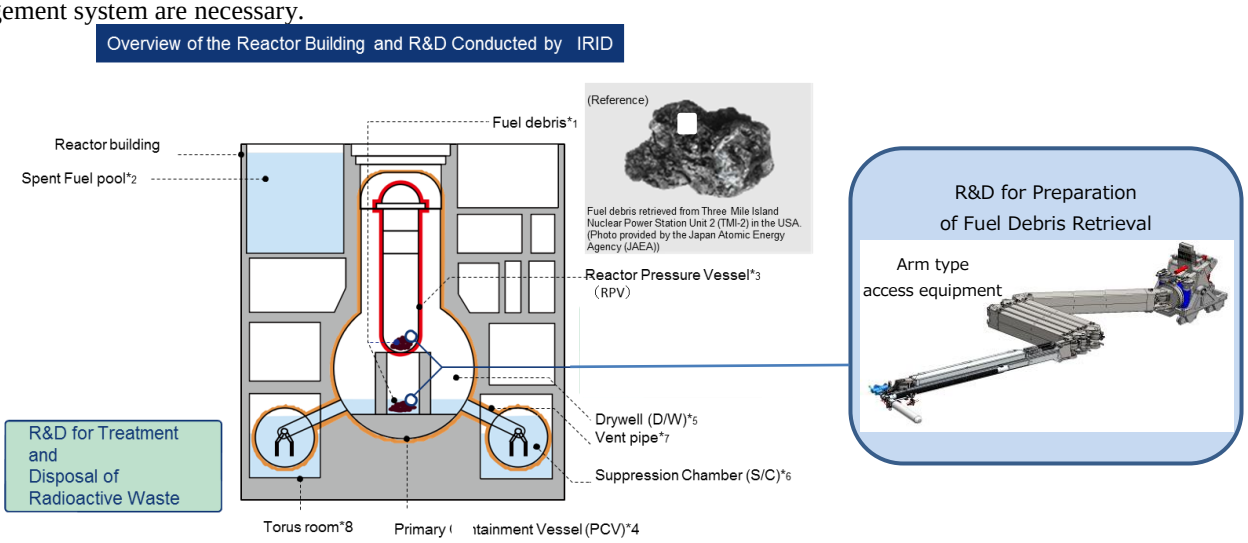
IRID proceeds with preparation of fuel debris retrieval based on a strategy indicated in the "*Technical Strategic Plan*" issued by the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF). IRID was developed element and robotic technologies for the Fukushima Daiichi.

First, detection technology to directly access fuel debris in the PCV was developed. In April 2015, a robot successfully entered the Unit 1 PCV. In FY 2016, a preparation for fuel debris investigation outside the pedestal started. At the same time, investigation robots for inside the pedestal, and remote-operated equipment to make an opening of the Unit 2 PCV penetration was developed to reduce worker's exposure. Additionally, fuel debris investigation inside the pedestal was conducted for Unit 3 by using an underwater swimming robot, and investigation equipment mounted a telescopic pipe and cameras for Unit 2. These robots can access fuel debris by remote operation and successfully obtained visual data of the PCV interiors. The Severe Accident Analysis Code was upgraded to identify fuel debris inside the reactor, and investigations through the cosmic-ray muon were performed. The distribution of fuel debris in the Unit 1 reactor was investigated from outside the reactor building by cosmic rays muon. The results of muon investigation revealed that almost no fuel remains in the reactor core. The muon transmission measurement was performed for Unit 2 from March to July 2016, and for Unit 3 from May to September 2017.

Furthermore, IRID developed the arm type access equipment to conduct a trial retrieval of fuel debris in the Fukushima Daiichi Unit 2 for more detailed investigation inside the PCV through the existing X-6 penetration. An original model of the investigation equipment is a robot arm used for maintenance of an experimental fusion reactor, placed in UK. The robot arm was redesigned to meet requirements for the Fukushima Daiichi.

2. Future Development

IRID aims to proceed with R&D for the decommissioning of the Fukushima Daiichi NPS and to acquire knowledge and expertise from around the world. Specifically, overseas technology for removal and storage of damaged fuel as well as the safety management system are necessary.



A04

Development of pipe inspection technology in high background radiation environment

Tatsuo Torii[1], Takahiro Hayashi[2] Takahide Sakagami[3], Shunsuke Kurosawa[4], Shohei Kodama[5] and Yuki Morishita[6]

[1]Univ. of Fukui, [2]Osaka Univ., [3]Kobe Univ., [4]Tohoku Univ. [5]Saitama Univ. [6]JAEA/CLADS

Abstract

In this research, in addition to miniaturizing existing non-destructive testing equipment, we will develop dedicated radiation detectors capable of non-destructively imaging the interior of pipes. Using laser-based and other non-destructive testing methods, we will acquire information about the interior of the pipes and clarify the presence of alpha radionuclides and the internal condition of the pipes.

1. Introduction

This study aims to comprehensively develop technologies to address three key needs identified by Tokyo Electric Power Company during interviews concerning internal pipe observation: 1) hydrogen content, 2) the presence of precipitates, and 3) the presence or absence of alpha/beta-emitting radionuclides. To achieve this, we are miniaturizing existing non-destructive inspection devices and developing specialized radiation detectors capable of imaging the interior of pipes without causing damage. This will enable the acquisition of information within pipes through non-destructive inspections using lasers and other techniques, allowing us to clarify the presence or absence of alpha radionuclides and the internal condition of pipes and other structures. The developed technologies are expected to be commercialized by Tokyo Electric Power Company and private-sector companies.

2. Research items and results

2-1. Development of pipe geometry visualization technology using non-destructive testing

This research category focuses on (1) remote evaluation of pipe deposits using laser ultrasonic measurement, (2) application of pipe inspection methods using active thermography, and (3) investigation of simple hydrogen gas detection methods. As shown in Fig. 1, we successfully visualized the location of wall thinning by measuring a test piece simulating pipe wall thinning using the thermography described in (2).

2-2. Development of non-destructive in-pipe radiation imaging technology

This research category is engaged in the development of (1) low-energy gamma ray detectors [1], (2) high-energy gamma ray detectors utilizing (α,n)(n,γ) reactions for detecting alpha rays in water, and (3) endoscope-type compact radiation measurement devices. As shown in Fig. 1, we have successfully developed a scanner capable of visualizing low-energy gamma rays.

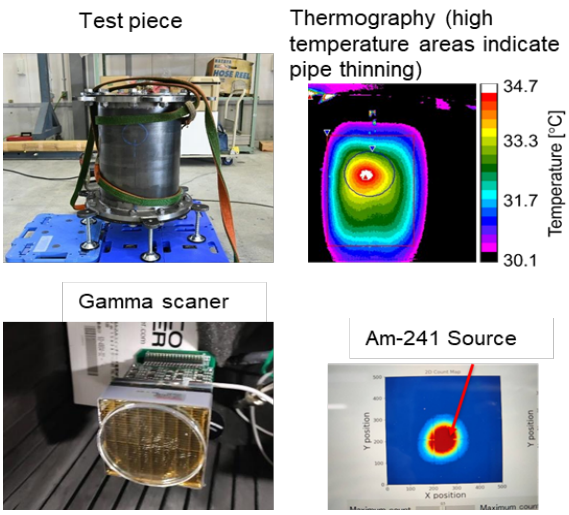


Fig. 1 Figure: Active thermography inspection device and low-energy gamma ray scanner developed in this project

References

[1] Morishita et al., Radiation Measurements, 183, 107414, 2025

A05 Research and Development of the Project of Decommissioning, Contaminated Water and Treated Water Management and Connection to Engineering

Fumiya Sato[1], Kota Sumida[1]

[1] Mitsubishi Research Institute, Inc. (Management Office for the Project of Decommissioning, Contaminated Water and Treated Water Management)

Abstract

The Ministry of Economy, Trade and Industry (METI) has established the fund since FY 2013 and implemented the "Project of Decommissioning, Contaminated Water and Treated Water Management" as a subsidy program by solicitations to support R&Ds with high technical difficulties. In this presentation, the connections among the various subsidized projects within this program and their expected contributions to decommissioning will be introduced.

1. Introduction

In order for the decommissioning of the Fukushima Daiichi NPS to be implemented safely and steadily, it is important to conduct R&Ds by gathering wisdom from both Japan and overseas. Therefore, METI has established the fund since FY 2013 and implemented the "Project of Decommissioning, Contaminated Water and Treated Water Management" as the subsidy program by solicitations to support R&Ds with high technical difficulties. The R&D projects have been managed by the Management Office for the Project of Decommissioning, Contaminated Water and Treated Water Management. In order for the results of the R&Ds to contribute to the decommissioning of the Fukushima Daiichi NPS, the R&Ds are conducted in cooperation with TEPCO, which manages the site and assesses its applicability.

2. Subsidized Projects of Decommissioning, Contaminated Water and Treated Water Management and Connection to Engineering

The R&D projects for the decommissioning of the Fukushima Daiichi NPS have been subdivided and subsidized. Each subsidized project is being conducted by domestic and foreign organizations. The subsidized projects are classified into "Internal Investigation", "Development of Fuel Debris Retrieval Method", "Improvement of Work Environment", and "Processing of Solid Waste, etc.". The R&D projects of Fuel Debris Retrieval have been conducted based on the information obtained by Internal Investigation. Additionally, the results of R&Ds such as Development of Fuel Debris Retrieval Method are reflected to Improvement of Work Environment. The R&D projects of Processing of Solid Waste are also studied in cooperation with R&Ds for Fuel Debris Retrieval Method and Improvement of Work Environment. In this way, current projects are linked to each other. In November 2024, the first successful fuel debris trial retrieval was carried out at the Fukushima Daiichi NPS Unit 2, with approximately 0.7 grams collected[1]. The second fuel debris trial retrieval was carried out in April 2025. These are important development in the decommissioning process, and it shall be more important to cooperate even more closely for the R&D projects. To obtain the information on R&Ds from domestic and foreign organizations, the Management Office is also conducting RFI (Request for Information) each spring on the website. (https://en.dccc-program.jp/)

References

[1] TEPCO, Unit2: The second fuel debris trial retrieval, FUEL DEBRIS PORTAL SITE, (https://www.tepco.co.jp/en/decommission/progress/fuel-debris/index-e.html?nuclear02&investigation5)

A06 The Study on the Influence of Different Dose Rates on Damage to Lubricants at the Same Total Dose

Yoshikazu Hayashi, MORESCO Corp. (hayashi@moresco.co.jp)

1. Abstract and Introduction

This presentation shows a part of findings from our ongoing joint study with QST on Radiation Damages to mainly the world's highest Radiation Resistant Lubricants, MORESCO-HIRADs.

So as to clarify the influence of different dose rates on lubricant exposure damage up to the fixed total dose as the world first, γ-irradiation was conducted for some oils with different dose rates up to a certain total dose in the study.

Consequently, the study has newly discovered that even though a total dose is the same, a difference in the damage to oil arises from dose rates leading up to it.

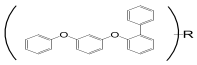
2. The γ-Irradiation Condition (from Co60)

【 The Dose Rates (MGy /h) 】 High rate : 0.00532 Low rate : 0.00266

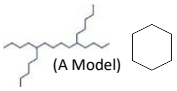
【 The Maximum Exposure Dose (Cumulative MGy) 】 5.0

3. The Molecular Structures of the Evaluated Oils and the Findings

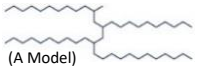
・MORESCO-HIRAD RP-42R (= The Radiation Resistant Oil) :

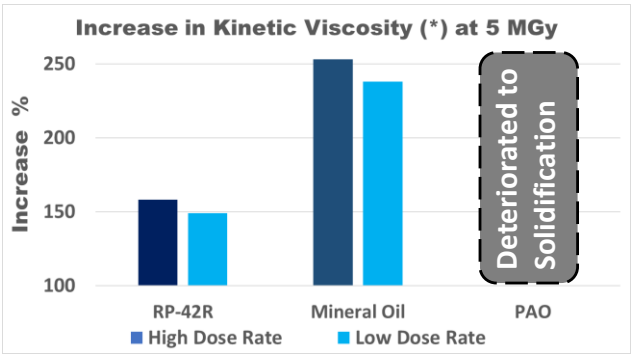


・Mineral oil :

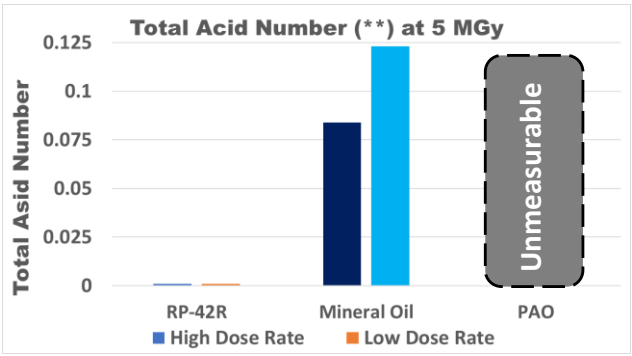


・Poly-Alpha-Olefin (= PAO) :



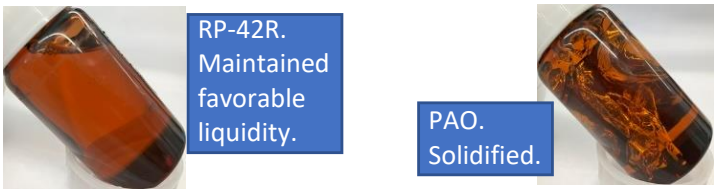


(*) Calculated by taking their values of unirradiated state as 100%. The higher the %, the more deteriorated.



(**) Indicates the degree of oxidative degradation. The higher the number, the more deteriorated.

【 A Refference: The Appearances 】
Irradiated RP-42R and PAO to 5 MGy with High Dose Rate



4. Conclusion

・It was identified that although a total dose was the same, there was a difference in the damage to oil due to the difference in dose rates leading up to it.

・In kinetic viscosity, both RP-42R and mineral oil are promoted alteration with a higher dose rate exposure than with that of a lower dose rate. In total acid value, oxidative degradation is promoted in mineral oil, with a lower dose rate exposure, contrary to that of the case in viscosity.

This is inferred to be because the longer exposure to radiation brought about by a low dose rate more promotes oxidation in mineral oil, which lack radiation resistance.

・Poly-alpha-olefin (PAO) was identified as being particularly susceptible to radiation, with that it deteriorated to a solid state under irradiation.

・RP-42R again demonstrated excellent radiation resistance even in this evaluation, with alteration resistance far superior to that of mineral oil and PAO.

A07 Research on physico-chemical behaviour of constitutional materials to understand the failure behaviour of pedestal concrete Second year progress

Go Igarashi[1], Aili Abudushalamu[1], Taito Miura[1], Ippei Maruyama[2], Shintaro Miyamoto[3], Takumi Sato[4], Xin Li[4], Ayako Sudo[4], Yuji Nagae[4]
[1]Nagoya Univ., [2]UTokyo, [3]Tohoku Univ., [4]JAEA

Abstract

In this study, we examined the mechanism of the collapse of only concrete with rebar remaining at the pedestal observed in the containment vessel (PCV) of the Fukushima Daiichi Nuclear Power Plant (1FNPP).

1. Introduction

In the internal investigation of the PCV of 1FNPP Unit 1 in 2022, a damage condition unique to Unit 1 was observed in which the concrete in the pedestal disappeared, leaving the rebar behind. In this study, we examined the concrete-specific and Unit 1-specific external environmental factors related to this phenomenon.

2. Summary of Studies

2-1. Concrete-specific factors: Short-term dissolution mechanism by high temperature

High-temperature heating experiments were conducted on cement paste, concrete aggregate, and their mixture to obtain thermal behavior data. Phase changes and melting behavior of heated concrete were analyzed using thermodynamic phase equilibrium calculations. A numerical model was also developed to simulate post-heating water absorption in concrete.

2-2. Concrete-specific factors: Long-term dissolution mechanism by temperature history

Conducted exposure experiments simulating the anticipated temperature and water injection history of the pedestal section. Measurements of the time-dependent expansion after high-temperature heating and observations of the expansion behavior due to moisture supply were carried out.

2-3. Special external environmental factors: Evaluation of concrete thermal conditions by heat transfer analysis of fuel debris

Referring to published accident scenarios, analysis parameters such as boundary conditions for debris accumulation in Unit 1 PCV during the accident were established. Heat transfer analysis of Unit 1 PCV was conducted to evaluate the thermal distribution within the concrete.

2-4. Special external environmental factors: Elemental behavior tests and comprehensive tests

To assess the impact of steam and temperature on the alteration behavior of concrete materials, a High Temperature Storage Test (HTS) was conducted in a steam atmosphere, evaluating the collapse behavior of concrete in the presence or absence of steam. Additionally, high-temperature reaction tests were conducted on simulated suboxide fuel debris containing uranium oxides and concrete to evaluate the damage behavior of concrete caused by reactions with the fuel debris.

3. Conclusion

This study provided comprehensive insight into the mechanism of concrete collapse in 1FNPP Unit 1.

4. Acknowledgements

This work was supported by JAEA Nuclear Energy S&T and Human Resource Development Project Grant Number JPJA23P23813418.

A08 Radiation-Hardened Serial Communication System with a Phase Adjustment Circuit

Utsuki Sekioka, Minoru Watanabe and Nobuya Watanabe
Okayama University

Abstract

It is known that permanent failures can occur on any Very Large-Scale Integration (VLSI) in strong radiation environments [1]. Currently available radiation-hardened VLSIs for space systems have a total ionizing-dose tolerance of up to 10 kGy [2]. The life-time is very short or 10 hours at a decommissioning site where radiation intensity of 1,000 Sv/h are expected. Robots used in decommissioning site must have high radiation tolerance. In addition, communication systems are required for controlling and monitoring the robots. Therefore, we have been developing a radiation-hardened serial communication system using a triple modular redundant (TMR) design on a DE1-SoC Field Programmable Gate Array (FPGA). By applying TMR design for the communication circuits and transmission lines, the total-ionizing-dose tolerance can be increased. However, since phase difference happens between communication lines, we propose a phase adjustment circuit.

1. Radiation-hardened serial communication system

The data structure of the TMR serial communication system is shown in Fig. 1. The data structure is similar to RS-232C consisting of 1-bit start bit, 8-bit data, 1-bit parity and 1-bit stop bit. In the communication system, three same signals are generated and transmitted. The overview of the TMR serial communication system is shown in Fig. 2. We prepare the three sets of communication cables to support triple redundant communication. However, there is a phase difference between the three lines. Therefore, we have developed a phase adjustment circuit for the TMR serial communication system. The phase adjustment circuit can adjust the phase for three signal lines by using shift register circuits.

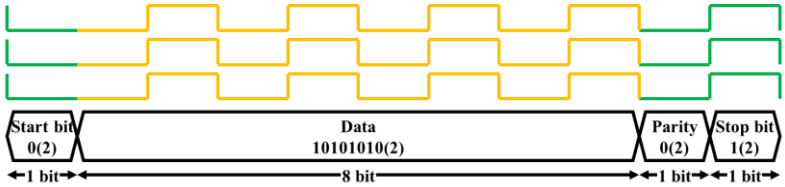


Figure 1. The data structure of the serial communication system.

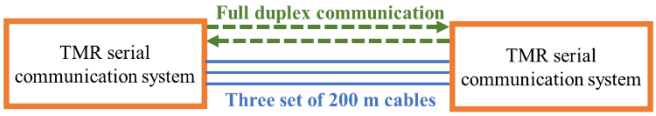


Figure 2. An overview of the serial communication.

2. Conclusion

We have realized a TMR serial communication system with a phase adjustment circuit on DE1-SoC FPGA. By using the phase adjustment circuit, the phase differences are aligned could be decreased to approximately 10ns.

References

[1] X. Zhang, Q. Guo, D. Zhou and Y. Li, “Total Ionizing Dose (TID) of Phase Change Random Access Memory,” 2021 4th International Conference on Radiation Effects of Electronic Devices (ICREED), pp. 1-6, 2021.

[2] XILINX. Radiation-Hardened, Space-Grade Virtex-5QV Family Data Sheet: Overview, https://docs.xilinx.com/ v/u/en-US/ ds192 V5QV Device Overview, 2018.

A09 Decommissioning research conducted by JAEA (4) Efforts regarding the disposal of radioactive wastes

Fumiya Nagao[1], Takuya Ohyama[1], Hiroki Hagiwara[1], Yusuke Watanabe[1], Mitsuru Sambongi[1] and Kazuki Iijima[1]

[1]Japan Atomic Energy Agency

Abstract

JAEA is conducting studies on the parameters of waste and the biosphere, disposal concepts, and safety assessment methods under quality assurance for the safety assessment of 1F waste, to support the 1F waste disposal strategy.

1. Introduction

For the safe disposal of the various solid radioactive waste produced during the decommissioning of 1F, we need to perform safety assessments. These assessments must consider uncertainties in the input data – including the characteristics of the waste, its form, and the expected disposal environment – and aim to reduce these uncertainties while evaluating safety based on them.

2. Effort on input data

The distribution coefficient K_d is the key parameter of the migration of radionuclide. To enhance understanding of sorption behavior of waste matrix such as cement and AAM, we are conducting sorption experiments and analyzing these samples using XRD, XPS etc. These results will be used to refine the model and improve its parameters. We are researching the migration behavior of uranium in the Ningyo-Toge area. The observation on deposit in the surface water shows U(IV) taken in ferric hydroxide deposit by redox reaction. The behavior of iodine is also targeted.

3. Effort on safety assessment

For the safe disposal of 1F waste, it is necessary to develop a disposal concept that addresses its diversity and uncertainties, and to evaluate its applicability. We have identified the possibility of achieving levels below the dose criteria with shallow land disposal for carbonate slurry through the enhancement of conventional disposal concepts. We establish the safety assessment method under quality assurance by preparing the documents of whole evidence and background data used in the safety assessment.

4. Conclusion

These results will be utilized to advance safety assessments and to streamline disposal of 1F waste, together with other studies on characterization and processing of waste.

Acknowledgement

This study was performed under the subsidy program “Project of Decommissioning, Contaminated Water and Treated Water Management (Research and Development of Processing and Disposal of Solid Waste)” conducted by the Ministry of Economy, Trade and Industry of Japan.

A10

Operating temperature range of ring oscillator circuits for a radiation-hardened optically reconfigurable gate array

Shintaro Takatsuki, Minoru Watanabe and Nobuya Watanabe
Okayama University

Abstract

Decommissioning robot must work at 1,000 Sv/h in the Fukushima Daiichi nuclear power plant. The lifetime of conventional VLSIs in such environment is limited to only 10 hours. In addition, crystal oscillator circuits are vulnerable to radiation. Our proposed Optically reconfigurable gate array (ORGA) consisting of a gate array VLSI, a laser array, and a holographic memory has 1 Grad total-ionizing-dose. This paper presents on-chip clock generation using ring-oscillator circuit.

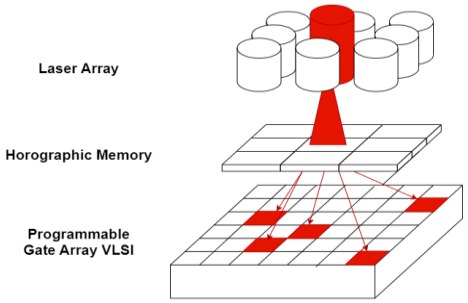


Figure 1. The Optically reconfigurable gate array (ORGA).

1. A flexible clock source using ring oscillators

To eliminate a crystal oscillator circuit in ORGA systems, we propose an on-chip clock generation using a ring oscillator circuit as shown in Fig.1 [1]. A ring oscillator implementation on an ORGA is shown in Fig. 2. The clock frequency is tuned by changing the number of inverter stages and adjusting the parasitic capacitance caused by wire length and switching matrices (SMs).

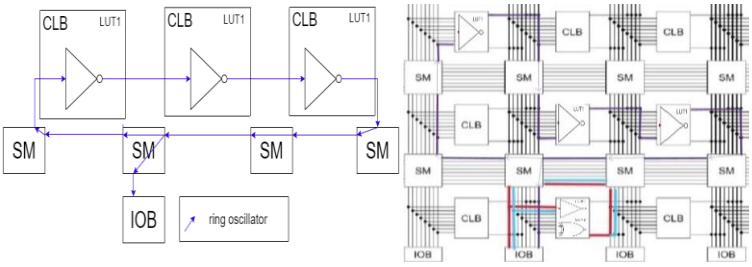


Figure 2. Ring oscillator implementation on an ORGA.

This implementation allows an ORGA to generate suitable clock frequencies. Furthermore, even if one ring oscillator fails due to radiation, since a new ring oscillator can be implemented onto another hardware resource, the robustness of the ORGA can be increased.

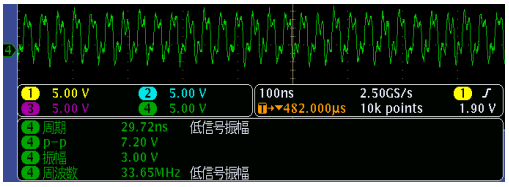


Figure 3. Ring oscillator operation.

2. Ring Oscillator in operation

A ring oscillator circuit was implemented onto an ORGA-VLSI as shown in Fig.3. The output clock frequency range is wide. An oscillator's temperature-dependent frequency was measured as 29.010 MHz to 33.797 MHz at temperature range from 15 °C to 60 °C.

Reference

[1] T. Fujimori, M. Watanabe, “Parallel light configuration that increases the radiation tolerance of integrated circuits,” Opt. Express, vol. 125, no.23, pp. 28136-18145, 2017.

A11

Evaluation of soft error tolerance on an optically reconfigurable gate array VLSI with a triple-modular redundant optical configuration circuit

Kiyoto Yonechi[1], Minoru Watanabe[1] and Nobuya Watanabe[1]

[1]Okayama University

Abstract

We have been developing an optically reconfigurable gate array VLSI. The VLSI can operate even if the programmable gate array has permanent failures by radiation. In addition, VLSI must have a scrubbing operation to increase the soft-error tolerance. Using the scrubbing operation, data on the configuration memory is cyclically repaired. In this study, we have implemented a new triple-modular redundant configuration circuit onto an optically reconfigurable gate array VLSI.

1. Optically reconfigurable gate array (ORGA) VLSI

Overview of an optically reconfigurable gate array (ORGA) is shown in Figure 1. An ORGA consists of three elements: programmable gate array VLSIs, holographic memory, and a laser array. The programmable gate array is similar to that of FPGAs. Holographic memory stores circuit information as interference fringes. Light emitted from the laser array passes through the holographic memory and is diffracted onto a lot of photodiode circuits on the programmable gate array VLSI.

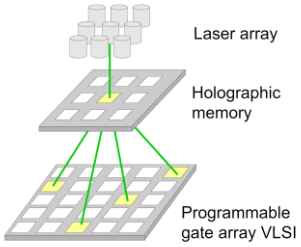


Figure 1. Optically reconfigurable gate array.

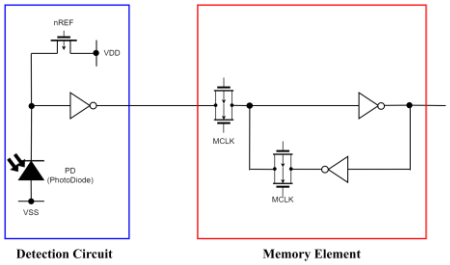


Figure 2. Structure of photodiode circuit.

2. Photodiode circuit

Figure 2 shows the structure of a photodiode circuit. A photodiode circuit consists of two elements: a photodiode and a memory element. The circuit consists of a refresh transistor, an inverter, and a photodiode. The photodiode circuit can convert from optical signal to electrical binary signal. Finally, the single bit signal is stored on a memory element.

3. Triple-modular redundant circuit for photodiode circuit

We implemented triple modular redundancy (TMR) for the ORGA-VLSI, and the photodiode circuits were also triplicated. Figure 3 shows the triple-modular redundant circuit. The photodiode structure is the same as shown in Figure 2. Memory elements are divided into master and slave sections. In the slave memory elements, majority voting circuits are employed. These majority circuits receive values from memory elements in other layers and continuously perform majority voting operation. This approach enables high-speed updating of the memory data within a period of 200 ps.

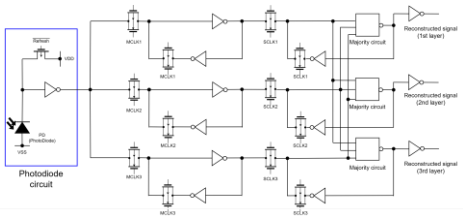


Figure 3. Triple-modular redundant circuit.

References

[1] T. Fujimori, M. Watanabe," High-speed scrubbing demonstration using an optically reconfigurable gate array," Optics Express, Vol. 25, Issue 7, pp. 7807-7817, 2017.

A12

VTR design tool for an Optically Reconfigurable Gate Array

Soma Imai, Minoru Watanabe and Nobuya Watanabe
Okayama University

Abstract

Robots must be used in the decommissioning of the Fukushima Daiichi Nuclear Power Plant. However, integrated circuits used in robots are vulnerable to radiation. In this paper, we present the customized Verilog-to-Routing (VTR) circuit design tool for optically reconfigurable gate arrays.

1. Optically reconfigurable gate array

An optically reconfigurable gate array consists of three components: an optically reconfigurable gate array VLSI, a laser array, and a holographic memory. Laser array addresses the data on the holographic memory. The addressed data is programmed onto the optically reconfigurable gate array VLSI. The configuration procedure can be executed in parallel. We have proposed a repairable VLSI concept that can extend the lifetime of an optical reconfigurable gate array VLSI.

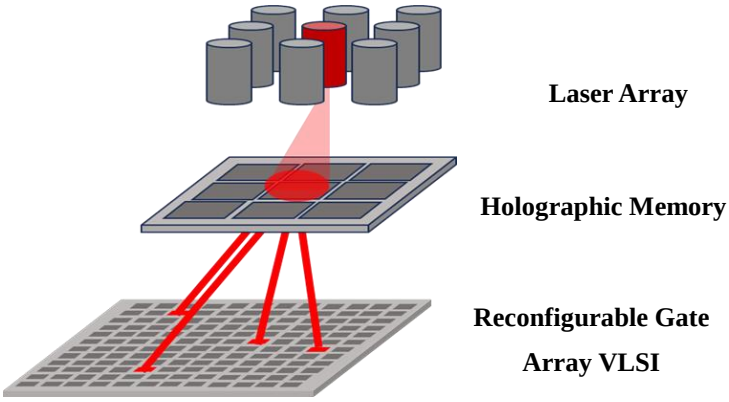


Figure 1. Structure of an optically reconfigurable gate

2. Verilog-to-Routing (VTR)

In this study, an open-source FPGA design tool VTR (Verilog-to-Routing) was customized for optically reconfigurable gate array VLSIs. VTR is a tool chain that can handle everything from logic synthesis to placement and routing. The programmable gate array architecture can be defined by XML format. By using the customized VTR, a processor operation could be implemented onto the optically reconfigurable gate array VLSI.

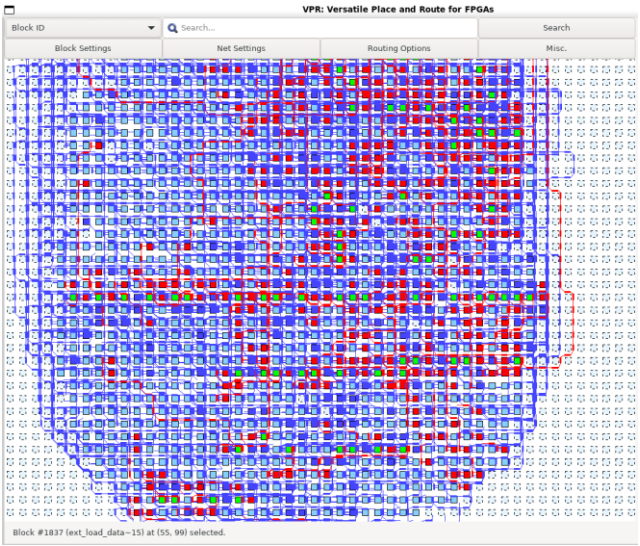


Figure 2. VTR placement and wiring results

A13 1FRAME: 1F Fuel Retrieval and Monitoring Experiments

G. McKenzie[1], D. Bowen[2], A. Chambers[3], D. Henzlova[1], A. Oizumi[1], S. Pignet[4], J. Hutchinson[1]
[1]Los Alamos National Laboratory, [2]Oak Ridge National Laboratory, [3]DOE-Nuclear Criticality Safety Program, [4]Authority for Nuclear Safety and Radiation Protection

Abstract

The 1FRAM E (1F Fuel Retrieval and Monitoring Experiments) project includes collaborative research and development in the area of neutron detection, analysis, and simulations for fuel debris removal at Fukushima Daiichi nuclear power station. Technical advances are needed in all three focus areas to provide technical recommendations on a course of action for fuel debris removal. This work is part of collaborative research and development efforts between the US, Japan, and France.

1. Introduction

The DOE-Nuclear Criticality Safety Program (NCSP) has a vision statement to provide a program that is "continually improving, adaptable, and transparent program that communicates and collaborates globally to incorporate technology, practices, and programs to be responsive to the essential technical needs of those responsible for developing, implementing, and maintaining nuclear criticality safety" [1]. This program has technical focus areas in integral experiments, analytical methods, and nuclear data. In recent decades, this has included research on neutron analysis methods, simulations, and detection [2]-[3]. The 1FRAME project builds on these capabilities and while focused on the application of 1F fuel debris removal. Specifically, this project aims to provide measured and simulated validation data which will test conditions similar to those in Units 1-3.

2. Approach

The 1FRAME project aims to predict and validate performance of radiation detectors within Units 1-3. This includes performing measurements with various detector systems in a high gamma flux environment. In addition, it includes advancing neutron multiplicity analysis methods to remove many assumptions and predict system parameters with limited information. In order to achieve this, several measurement campaigns will be needed. These will include "blind tests" in which system parameters (such as system multiplication) are changed and those changes are predicted using measured data. Such experiments are essentially mock-ups of fuel debris removal operations.

3. Conclusion

Advances in neutron detection, analysis, and simulations will have many benefits including the ability to perform neutron mapping of 1F units and the ability to provide data which can be used to make important decisions during fuel debris removal.

References

[1] The Mission and Vision of the United States Department of Energy Nuclear Criticality Safety Program, https://ncsp.llnl.gov/sites/ncsp/files/2021-04/ncsp_mission_vision.pdf

[2] J. Hutchinson, et. al., "Validation of statistical uncertainties in subcritical benchmark measurements: Part II – Measured data," Annals of Nuclear Energy, 125, 342-359 (2018).

[3] E. Dumonteil, et. al., "Patchy nuclear chain reactions," Nature Communications Physics, 4:151 (2021).

A15

AtkinsRéalis

Increasing Efficiency of Nuclear Decommissioning with Virtual Site Access

Sam Stephens and **Ehui Chong**

AtkinsRéalis, United Kingdom

Abstract

As digital transformation reshapes infrastructure management, the ability to remotely access and monitor nuclear sites has become essential. In response, AtkinsRéalis developed Virtual Site Access —a comprehensive service that captures and processes site data for secure, real-time access via a secure cloud hosted platform. Originally created during the pandemic to mitigate travel risks and support remote collaboration, Virtual Site Access continues to provide value across a range of use cases, including reality capture, remote expertise, and construction monitoring.

Virtual Site Access is an innovative suite of services developed by AtkinsRéalis to enable remote management of critical nuclear sites. Leveraging advanced tools such as robot-mounted cameras, 3D laser scanners, drones, and quadrupedal robotics, Virtual Site Access captures comprehensive onsite data to create a digital replica of the physical environment. This data is securely hosted on AtkinsRéalis' cloud-based digital twin platform.

By integrating cutting-edge technologies and industry-standard tools, Virtual Site Access enhances site understanding, reduces the need for physical presence, and delivers significant savings in time, cost, and carbon emissions—while improving safety, collaboration, and knowledge sharing.

This paper discusses key elements of the virtual site access service and how they integrate with nuclear decommissioning project delivery to improve collaboration between teams on and off site and reduce risks to people and the environment. The service is delivered through three distinct stages from deployment on site, to processing in the office to sharing on the cloud:

- **Deploy**: Utilises tools on site such as LiDAR, drones, 360° cameras, and quadrupedal robotics to collect high-value visual data—often more cost-effective and informative than traditional point cloud or BIM models.
- **Process**: Manages and processes spatial data securely, with options for desensitisation to meet information assurance & security requirements associated with cloud storage of sensitive data.
- **Share**: Enables secure, remote access to site data through cloud platforms, with support for immersive technologies like Extended Reality (XR) to enhance visualisation and collaboration.

By offering a scalable, secure, and efficient approach to site management, Virtual Site Access empowers project teams to make informed decisions and maintain continuity without the constraints of physical site visits.

B01

Application of Remote Strain Measurement Technology to Decommissioning and its Prospects

Akihiko Nishimura[1,2], Tsugio Ide[3] and Nobuyuki Ishihara[3]
[1]JAEA, [2]Univ. Fukui, [3]deltafiber.jp

Abstract

The application of remote strain measurement technology using FBG sensing products to decommissioning and its prospects were reported along with an introduction of products produced through technology transfer.

Measurement of strain and temperature under high radiation doses is an important fundamental technology not only for the development of new reactors but also for decommissioning. The technology transfer from JAEA to companies has been completed, and stable supply of heat-resistant and radiation-resistant FBG sensors by picosecond laser processing is now possible in Japan [1]. Currently, we can supply FBG sensors that meet user needs through a made-to-order production system.

Figure 1 shows the exhibition of FBG sensor-embedded products at the 20th Japan Society of Maintenance Engineering Conference. Decommissioning equipment for the Fukushima Daiichi nuclear power plant, fuel reprocessing plants, next-generation reactors and nuclear fusion reactors as well, FBG sensors should preferably be mounted on key points of facilities and equipment prior to use. Secondarily, Figure 2 shows a stainless-steel bolt with an embedded FBG sensor, commonly referred as ‘bolt gauge’. This makes the installation of sensors on-site significantly easier. The bolt size was M16, and a small hole was created in the center axis of the bolt by electric discharge machining, the FBG sensor was embedded, and the cavity was filled with an adhesive was filled and then cured. The embedded FBG bolt gauge, initially developed for nuclear decommissioning applications, also holds potential as a structural health monitoring device in existing infrastructure, such as earthquake-resistant reinforcements. Finally, fuel debris that has been in water for a long time and is emitting radiation may become brittle due to corrosion, so it is desirable to handle the debris by controlling the retention force. A master slave manipulator in hot cells with a gripping force sensing function is shown in Figure 3. Roberval-type tip metal fittings are mounted on the gripping mechanism, and a demonstration experiment is being conducted to measure the weight of simulated debris using a pair of FBG sensors [2]. An example of mounting FBG sensors on a crane arm is introduced.

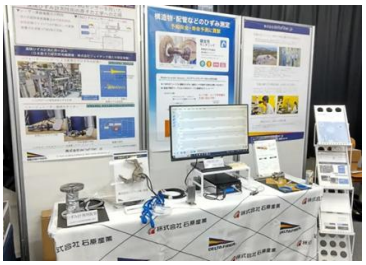


Fig. 1 Exhibition of products

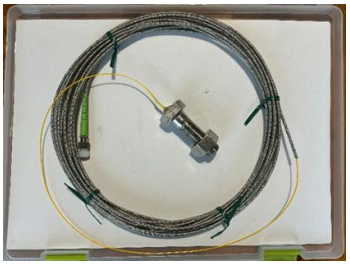


Fig. 2 Bolt-type FBG strain gauge

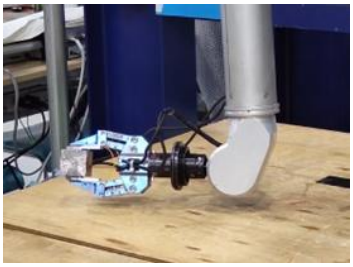


Fig. 3 MSM with griping force detection

The equipment and demonstration plant for mounting FBG sensors were kindly provided by J-tech Corporation [3]. We would like to express our sincere gratitude.

References

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B02 How digital simulation optimises decommissioning projects and waste-led strategies

Jean-Luc Flouttard[1], Nicolas Andrews[2], Guillaume Brunel[3]
[1]Cyclife Digital Solutions, France [2]EDF DP2D, France [3]Cyclife Japan, Tokyo

Abstract

Drawing on two use cases involving projects that use our simulation software, DEMplus® and FlexSim®, we will demonstrate how three-dimensional (3D) digital simulation tools are becoming an increasingly valuable resource for nuclear decommissioning activities, including scenario studies, the development of innovative remote technologies, detailed working methods, and waste management.

1. Introduction

Three-dimensional (3D) digital simulation tools are increasingly being used to study scenarios and support the development of innovative remote technologies and detailed working methods, and waste management associated with nuclear decommissioning activities.

We will present the results of two use cases involving projects that use simulation software: DEMplus® and FlexSim®.

2. Digital simulations for nuclear decommissioning operations at the EDF Fessenheim Power Plant in France

2-1. Decommissioning scenario studies

The first use case focuses on the decommissioning simulation strategy for the EDF Fessenheim power plant in France. Several decommissioning scenarios were simulated and compared, prioritising occupational radiation exposure. This made it possible to mitigate hazards and secure the critical path by identifying critical elements. DEMplus® software was used for this use case to optimise scenarios based on real-time 3D simulations that assess costs, lead times, waste streams and dosimetry simultaneously.

DEMplus® *for nuclear*, a 3D digital software developed by Cyclife Digital Solutions, has been adopted by several nuclear industry leaders in France and around the world in recent years. It is a decision support tool that addresses the challenges of working in nuclear environments, helping leading engineering companies to define operational strategies. Thanks to its comprehensive approach, DEMplus® enables the implementation of the ALARA/ALARP (As Low As Reasonably Achievable/Practicable) methodology.

2-2. Waste stream logistical study

The second use case is a waste logistical study in which FlexSim® software is used to simulate the evacuation of waste generated by decommissioning processes. A simulation model has been developed that considers the activities of each decommissioning project, such as human resources, transportation and scheduling. This project aimed to simulate all waste streams generated by dismantling activities, optimise storage area capacity, identify bottlenecks and constraints, and define the necessary human, material and physical resources to enhance the strategy. The Figure 1 is a presentation of various operating levels in the Reactor Building 2 in Fessenheim NPP prior to logistical simulation.

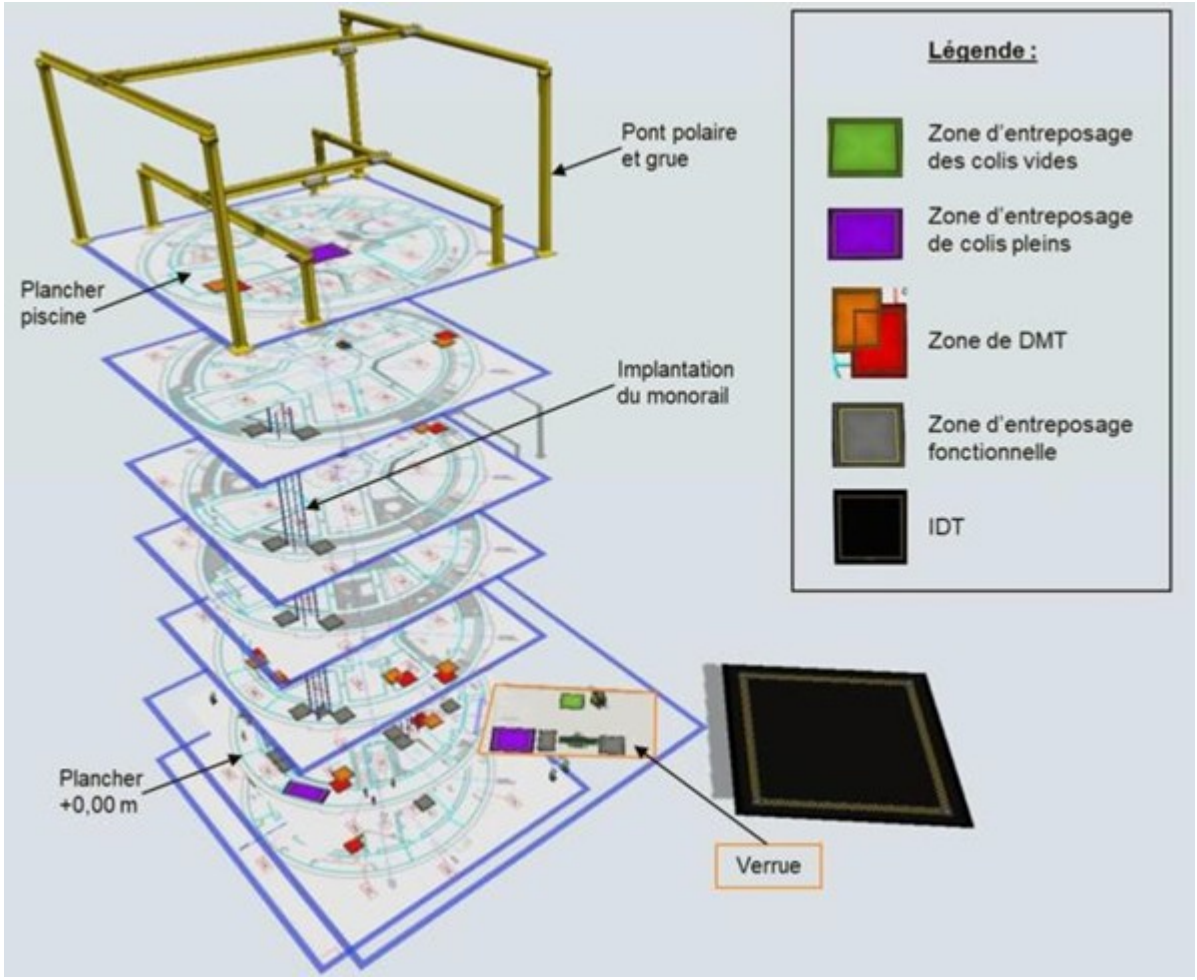

Figure 1. Logistical flow study in the Reactor Building 2 in EDF Fessenheim NPP

3. Conclusion

Two use cases involving decommissioning projects that use simulation software that could be adjusted and expanded to other decommissioning conditions.

B03 Development of a Common Robot Network Platform Using RSNP

[1,4]Nobuto Matsuhira, [2]Young-woon Song, [3]Kanzhong Yao, [3]Christopher Bishop, [3]Keir Groves, [3]Simon Watson, [4]Takeshi Sasaki, [1]Atsushi Yamashita, and [1]Hajime Asama

[1]The Univ. of Tokyo, [2]POSTECH, [3]The Univ. of Manchester, [4]Shibaura Institute of Technology

Abstract

As societal challenges become more complex, robots are increasingly desired for problem-solving. By networking robots and sensors using the common protocol Robot Service Network Protocol (RSNP), we have developed a platform to address such issues. We implemented a control system for seamless switching between remote operations and autonomous navigation of connected robots in confined spaces, with useful functions.

1. Introduction

For the decommissioning of the Fukushima Daiichi Nuclear Power Station, various types of robots have been introduced. Robotic technologies are expected to play a significant role in tasks such as fuel debris removal and related operations. To ensure the continuity of these long-term efforts, commonality and standardization are essential. In response to these complex social challenges, a common robotic platform has been developed. This paper discusses the system specifications necessary to implement and expand the application of this platform.

2. Common Robot Network Platform (Collaboration Platform)

2-1. Architecture

The developed architecture is based on the following three requirements:

(1) Provision of a management platform for robots and devices.

(2) Compatibility with heterogeneous robots and devices.

(3) Capability for remote management and control of robots.

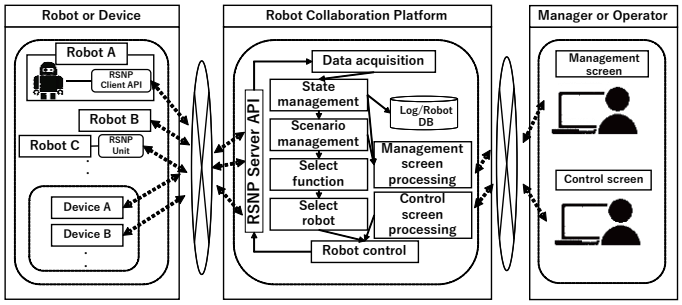

Figure 1. A monitoring platform concept

The architecture is composed of three main components: Robot/Device, Robot Collaboration Platform, and Manager/ Operator, as illustrated in Fig.1.

2-2. Common platform specifications

(1) Easy networking involves various types of robots and sensors: RSNP is a standardized protocol for robots over the Internet, and this protocol has been adopted in our research projects.

(2) Unified operation across robot types: Arrow keys and function keys are used in the GUI for robot control, as these are commonly used in game controllers.

(3) Customizable and consistent GUI design: The GUI is built using a Web API, and a basic design has been developed so it can be easily modified on the server side.

(4) Seamless switching between teleoperation and autonomous control: Users do not need to be aware of or make changes to the control modes and can operate a robot according to their wants.

(5) Data utilization: Users can access and utilize data sent by each robot and sensor stored in the database.

2-3. Developed functions to support robot collaboration and adaptability in various environments.

(1) Inter-robot communication via MQTT for coordination in narrow spaces.

(2) Obstacle avoidance during manual operation.

(3) Interaction with environmental characteristics for adaptive obstacle detection range.

(4) Object detection using both local and cloud-based resources.

(5) Manual recovery from stacking situations.

3. Conclusion

Research and development have been carried out on a common robotic network platform designed to address social challenges. The specifications of the platform are described based on the developed system. We plan to enhance the system for application at the Fukushima Daiichi Nuclear Power Station.

This work was partially supported by JAEA Nuclear Energy S&T and Human Resource Development Project Grant Number JPJA24H24020026 and OECD/NEA NEST ARTERD.

B04

Development of an Integrated Management Support System for Nuclear Decommissioning

Sam Stephens and **Ehui Chong**

AtkinsRéalis, United Kingdom

Abstract

Complex decommissioning projects in high-hazard environments demand meticulous management and coordination across all aspects of delivery. These include design, manufacture and installation; personnel training; workforce management; and project and risk management. Digital solutions to support these functions are widely available, and opportunities are now emerging to integrate them—enhancing efficiency and reducing delivery risk.

AtkinsRéalis evaluated emerging technologies, delivery methodologies, and lessons learned from world renown nuclear decommissioning projects. This led to the development of an integrated management software architecture designed to support the safe, effective, and efficient execution of decommissioning activities.

The investigation focuses on four key functional areas, each informed by insights from industry subject matter experts and AtkinsRéalis' deep understanding of commercial off-the-shelf (COTS) technologies currently deployed at nuclear facilities and decommissioning sites worldwide. These core components include:

- Engineering and Information Management
- Project and Program Management
- Workforce Management
- Asset Operations and Management

To support implementation, AtkinsRéalis developed a digital transformation roadmap based on best practices in digital engineering for asset management and project execution—both within the nuclear sector and across other large-scale infrastructure environments. A well-architected, integrated management system can streamline operations, enhance data integrity, and strengthen compliance oversight.

This system architecture diagram represents the next generation of digital solutions—purpose-built to optimize site operations while improving safety and operational efficiency.

C01

Study on volatile Cs compounds interaction with structural steel and metallic debris during the 1F accident

Anton Pshenichnikov, Hiroshi Ohgi, Bella Zubekhina, Hai Pham
Japan Atomic Energy Agency, Tomioka, Fukushima, Japan

Abstract

The current internal situation inside the Fukushima Dai-Ichi Nuclear Power Station (1F) is largely unclear, because of the high dose rate produced by Cs radioactive isotopes. Large-scale investigations and decommissioning operations on the 1F site is still a challenge. Thus, an investigation of an interaction of CsOH with stainless steel 316L, simulated metallic debris from the CLADS-MADE tests [1] seems helpful in clarifying the Cs behaviour during the 1F accident. The study attempts to answer the questions:

- What are the mechanisms and conditions of Cs retention on oxidized metallic surfaces?
- How deep can Cs penetrate into material during short-term interaction (1-3 hours)?
- What are the new species formed as a result of Cs – metallic debris interaction?
- What are their properties important for the decontamination of oxidized metallic surfaces?

A large number of laboratory small-scale high-temperature interaction tests of the simulated debris with Cs compounds have been performed. The conditions were chosen to cover the whole range of temperatures and debris compositions, which could potentially emerge during the 1F accident.

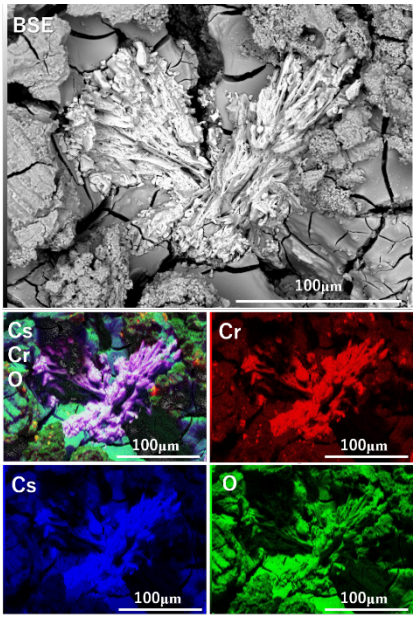

Figure 1. Cs_2CrO_4 compound on the surface of simulated debris [3].

The results show that from 500 to 1000 °C, CsOH reacted with preoxidized stainless steel and metallic debris in a temperature range, with Cs retention on the surface (as a new compound) and with the penetration into oxide layer. The experimental data is fully supported by the thermodynamic modelling, which show under which condition the reaction is possible.

An appearance, elemental and phase composition of new-formed caesium chromate Cs_2CrO_4 (Figure.1) and caesium molybdate Cs_2MoO_4 were confirmed on the surface of the samples at temperatures of 500 – 700 and 700 – 900 °C, respectively. Over 950 °C Cs remains within the oxidized layer to the whole depth and is unable to penetrate to alloy under maximum 3 hours of accident conditions at 500-1000 °C.

The problem of Si interaction with Cs was proved irrelevant for debris and steel because of vanishing amount, but maybe still important if concrete sample is heated to abovementioned temperatures. Unfortunately, it was not in the focus of this study.

In conclusion, an important background information on the mechanisms of clean up was provided. Authors hope that by means of analysis of the Cs compounds, temperature distribution during the accident can be clarified and included into the debrisEye map jointly developed by JAEA [2]. Based on this research a recent paper by the authors [3] suggests potential perspective for volume reduction of the disposed nuclear waste at the 1F.

References

[1] [1]

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C02

An Example of Thermodynamic Approach Efforts to Estimate Concrete damage behavior in 1F Unit 1 pedestal

Hiroshi Ohgi

Japan Atomic Energy Agency, Tokai-mura, Ibaraki, Japan

Abstract

Investigations inside Fukushima Dai-Ichi Nuclear Power Station (1F) Unit 1 pedestal had revealed the concrete collapsing and the rebar exposure, indicative of the potential for Molten Core Concrete Interaction (MCCI) and the concrete melting under low-temperature conditions. Preliminary thermodynamic assessment using the TAF-ID database developed as OECD/NEA project suggested a solidus temperature of approximately 1050-1100 °C for the SiO_2-based concretes. Assessment of the database through the detailed sim-concrete melting experiments is ongoing.

1. Introduction

During investigations inside 1F Unit 1, the concrete collapsing and the rebar exposure were observed at the bottom of the pedestal. This collapse suggests probable reactions with MCCI and the concrete melting under low-temperature conditions. It is an important issue to understand this mechanism for refining 1F accident scenario and improving estimates of conditions inside the reactor. In addition, the debris/concrete interaction system (U-Zr-Fe-Cr-O / SiO_2-Al_2O_3-CaO) has been selected as one of the most important 19 systems of the System Identification and Ranking Table (SIRT) in TCOFF-II (Thermodynamic Characterisation of Fuel Debris and Fission Products) project[1] . It is attracting attention as an issue that requires priority experimentation. In this study, a preliminary thermodynamic analysis was performed on the concrete melting mechanism using Thermodynamics of Advanced Fuels - International Database (TAF-ID)[2], which is currently under development at the OECD/NEA international project.

2. Efforts to Improve Thermodynamic Data and Analysis

We carried out the concrete-related thermodynamic assessment using TAF-ID database. In TAF-ID (Version 19, 2025), only quasi-binary systems such as FeO_X-SiO_2 were stored as the concrete data at this time. The thermodynamic analysis result for concrete melting using TAF-ID was shown in Figure 1. The solid phase region of concrete is shown in green, and the solidus temperature of the SiO_2-based concrete widely used on 1F was estimated to be approximately 1050-1100 °C. This suggests that concrete may have begun to melt at a temperature lower than the rebar's melting point, which could explain only the concrete collapsed in Unit 1, also from a thermodynamic perspective.

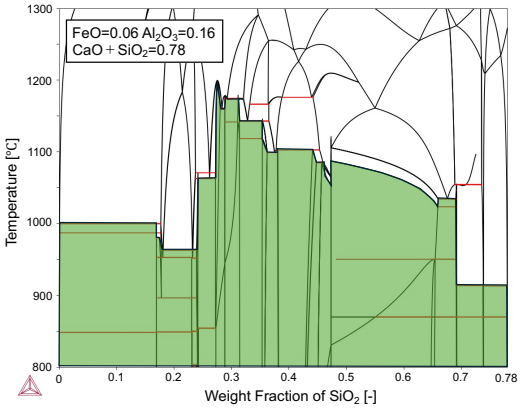

Figure 1. Quasi-binary phase diagram for the Si-Ca-Al-Fe-O system concrete

References

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C03 Estimation of status inside the PCV in unit 2 using results of analysis of samples from trial fuel debris retrievals

Masato Mizokami[1], Mutsumi Hirai[1], Shinya Mizokami[1,2] and Hirotomo Ikeuchi[2]
[1]Tokyo Electric Power Company Holdings, Inc., [2]The Japan Atomic Energy Agency

Abstract

Fuel debris at Fukushima Daiichi Nuclear Power Station Unit 2 have been retrieved during trial retrievals. An estimation of the situation inside the containment vessel was done with the information obtained from the sampling points and the results of fuel debris analysis.

1. Introduction

At Fukushima Daiichi Unit 2, trial retrievals using a telescopic device were successfully conducted in October 2024 (1st time) and April 2025 (2nd time). Figure 1 shows an overview of the sampling locations. The first fuel debris was taken from the periphery of the pedestal inside and the second fuel debris was more towards the central area. Both samples were collected by suspending a sampling device (gripper) from the missing grating on the platform. The acquired fuel debris is currently being analyzed at off-site facilities.

2. Estimation Methodology

2-1. Results of external appearance observations and surface analysis [1]

External photographs of the first and second fuel debris are shown in Figure 2. The first fuel debris had rounded, smooth surfaces, whereas the second fuel debris was angular in shape. In the first fuel debris, U, Zr, Fe, Cr, Ni, O, etc. were detected on the surface.

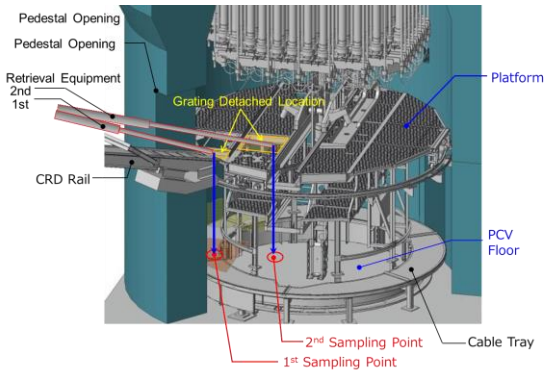

Figure 1. Overview of the extraction locations

Figure 2. External appearance of Fuel Debris
(Left : 1st approx. 0.7g, approx. 9mm x 7mm,
Right : 2nd approx. 0.2g, approx. 5mm x 4mm)

2-2. Evaluation of solidification process

For the first fuel debris, based on the rounded structure of its surface and the results of elemental analysis of the surface, it is presumed that the melt of U-Zr-Fe-Cr-Ni-O solidified and formed. By comparing the results of thermodynamic calculations with the composition and proportion of each phase from future detailed analysis, we believe that a more in-depth evaluation of the solidification behavior can be obtained. This may contribute to a better understanding of the properties of fuel debris itself, consequently that of the status in PCV.

2-3. Variation in U isotope ratios

The distribution of enrichment (^{235}U/total U) existed in the core prior to the accident were less than 1% to 5%. On the other hand, the enrichment of samples (other than fuel debris) collected so far in Unit 2 has been found to be generally around 2%, close to the core average value, which may indicate a tendency of homogeneity by melting and mixing. In the future, when the degree of enrichment of the fuel debris is clarified by chemical analysis, discussions of these effects may be possible.

References

[1] JAEA, TEPCO, NDA & Frac. of fuel debris, Jan. 30, 2025. [2] JAEA, TEPCO, NDA of fuel debris(2nd), May. 29, 2025.

C04 Current Status of Analysis of Fuel Debris Obtained from the First Trial Retrieval at Fukushima Daiichi Nuclear Power Station Unit 2

Hirotomo Ikeuchi[1], Hideki Ogino[1], Koji Maeda[1], Toru Kitagaki[1],
Masaaki Kobata[1], Tohru Kobayashi[1], Masato Mizokami[2] and Shinya Mizokami[2]
[1]Japan Atomic Energy Agency, [2]Tokyo Electric Power Company Holdings, Inc.

Abstract

To proceed the decommissioning of Fukushima Daiichi Nuclear Power Station (FDNPS), analysis of the fuel debris obtained from the trial retrieval at Unit 2 is underway to characterize their properties. This presentation will report key findings from various analyses, including non-destructive analysis, solid analysis, and solution analysis.

1. Introduction

Characterization of the fuel debris accumulated in the PCVs and RPVs of FDNPS Units 1 to 3 is essential for safety assessments related to the retrieval and storage of fuel debris and planning for their disposal. The first trial retrieval by TEPCO HD was completed in November 2024, resulting in the acquisition of a single pebble-like sample (Figure 1) from inside the pedestal of Unit 2. This sample is currently undergoing various analyses at multiple hot labs in Japan to determine its characteristics.

Figure 1. Appearance of the fuel debris sample[1]

2. Current Overview of Analysis

Non-destructive analysis confirmed the presence of fuel-derived components such as U, and subsequent crushing successfully fragmented the debris into multiple pieces. These fragments were then distributed to hot labs for detailed solid and solution analyses. Microscopic examination of fracture surfaces and cross sections revealed the presence of phases including U-Zr oxides, Fe-Ni metals, and Fe-Cr oxides, indicative of structural material oxides and reaction products with the fuel. Synchrotron radiation analysis demonstrated differences in the oxidation state and crystallinity of uranium between the sample's interior and surface. Solution analysis of a sample portion revealed that the number of moles of structural material components (Zr, Fe, Cr, Ni) exceeded that of the fuel component (U). These findings suggest that the sample's formation involved oxidation and melting of the structural materials.

Acknowledgements

This presentation includes results of the subsidy project (development of analysis and estimation technology for characterization of fuel debris) related to the subsidy for decommissioning, contaminated water, and treated water countermeasures project started 2023FY.

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D01

The World's Highest Radiation Tolerant Performance Camera

Shigemasa Oga and Sora Onishi
CORNES Technologies Ltd.

Abstract

Mirion Technologies (IST) Ltd. is an industry leader in supply of Radiation Tolerant Cameras and specialist CCTV & imaging systems for the Nuclear Industry. The Mirion IST-Rees brand of radiation tolerant cameras is recognized as the market leader in the Nuclear Industry (Power Plant, Reprocessing and Decommissioning) worldwide. With a comprehensive range of products to suit all applications in every part of the Nuclear fuel cycle, Mirion is able to offer standard or customized solutions to meet customer needs and expectations.

Hyperion™ Compact Camera System

The Hyperion Compact Gen II Camera follows many years of extensive Research and Development and considerable investment in new technologies. Featuring all new Radiation Tolerant zoom lens and optics with integrated pan and tilt, this new version offers all the benefits of the earlier generation Hyperion camera but in a lighter and more compact outstation. The Hyperion camera has been independently tested to 1 MGy with Cobalt-60 sources.

In addition, Mirion is pleased to offer both monochrome and color variants without a pan/tilt unit for even greater deployment flexibility on Servo-Manipulators, custom deployment mechanisms, and tooling applications.

Solid-State, 1M Gy Radiation Tolerant & Robust Camera

- 100 Mrad / 1 MGy total dose (gamma)
- Digital performance, high radiation tolerance
- Color or Monochrome options
- Pan/Tilt-free version available
- In air or underwater operation
- System-on-Chip flexibility
- Superior picture geometry
- High performance solid-state 1x megapixel sensor
- Low cost of ownership, driven by low maintenance and long life

Web Application operation

The camera video stream can be viewed, and the camera controlled using a web application via Ethernet.
The System provides a web application on the camera IP address on a port number as set by the camera configuration.
The web application can be accessed by a web browser connecting via HTTP.

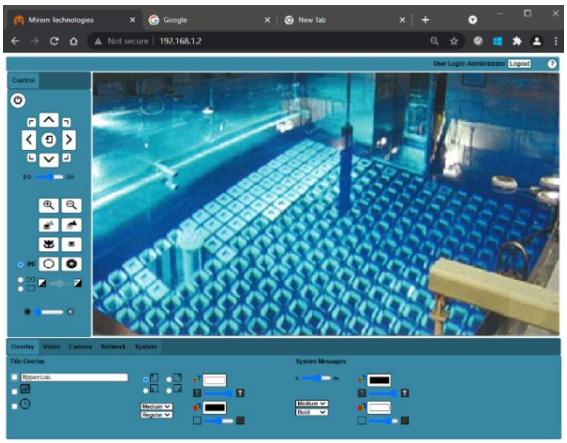


Figure1: Web application

Conclusion

The new Hyperion Compact high radiation tolerant digital cameras extends on our years of research and development into digital radiation tolerant electronics combined with our unique Mirion color processing algorithms to provide an unsurpassed user experience for high radiation tolerant imaging.

E01 Establishment of Tousou Mirai Manufacturing Co., Ltd. and Manufacturing Plans for Decommissioning Products.

Tomokazu Harada[1]

[1] Tousou Mirai Manufacturing Co., Ltd.

Abstract

Tousou Mirai has been established to support the decommissioning work at both Fukushima Daiichi Nuclear Power Plant and Fukushima Daini NPP with providing spent fuel casks, fuel debris storage containers, and other products. We will contribute to the reconstruction of Hamadori area and Fukushima Prefecture by constructing a factory and manufacturing products. Construction plan for the factory has been developed.

1. Introduction

We will create jobs in Hamadori area and provide employment opportunity for local graduated students and residents by manufacturing nuclear power components including spent fuel casks in Fukushima.

2. Location of Cask Factory

The cask factory is to be built outside of restricted area of Fukushima Daini NPP.

3. Four Safety Functions Required for a Cask

1. Prevention of Criticality, 2. Radiation Shielding: Reducing the effects of radiation outside the cask below acceptable levels, 3. Confinement: Preventing leak of radioactive materials from the cask body to the outside, 4. Heat Removal: Removing spent fuel's decade heat from the cask surface and Keeping cask temperature below acceptable levels.

4. Schedule

We aim to start construction of the factory by the end of first half of fiscal 2025, start production of the first unit by the end of fiscal 2027.

5. Conclusion

TEPCO is working on contribution to reconstruction of local area and decommission of NPPs. Kanadevia is a nuclear power components supplier and has expertise of manufacturing spent fuel storage and transportation casks. Tousou Mirai has been established by bringing both parties' skills and knowledge together and aims to become a company rooted in the community.

Image of cask factory

E02

Construction status of large cover for fuel removal from Fukushima Daiichi Nuclear Power Station Unit 1 and removal of existing damaged steel frames using remote-controlled machine

Hiroshi Noda[1], Masato Hosokawa[1], Kenichi Akamaru[1], Naoto Kibe[1], Yusui Ishida[1],
Kakuei Kawaguchi[1]
Kenji Toyoshima[2], Akio Hirata[2], Miho Miyazaki[2], Ippei Matsuo[2], Masataka Nishioka[2],
Ryota Mizutani[2]
[1]Tokyo Electric Power Company Holdings, Inc.
[2]Kajima Corporation

Abstract

This paper presents current construction status of large cover for fuel removal from Fukushima Daiichi Nuclear Power Station Unit 1 and removal of existing damaged steel frames using remote-controlled machine.

Construction Status of large cover

Large cover consists of a temporary base, lower frame structure, upper frame structure, box ring and retractable roof. The temporary base is the platform for construction of the retractable roof. The structure above lower frame structure is supported by the outer wall of the existing structure using 3,500 anchor bolts and 184 base plates. It is planned to construct large cover first, which is supported from reactor buildings, and high-dose debris will be removed from operating floor remotelyas well. After that, the spent fuel will be removed. Under the latest construction status, installation of upper frame structure is almost completed, and installation of the box ring has begun.

Removal of existing damaged steel frames using remote-controlled machine

It was necessary to remove existing damaged steel frames that was interfering with shielding to be installed inside large cover. To reduce the radiation exposure of workers, remote-controlled machines were used for the removal. Two machines were developed, one for cutting columns and one for cutting beams, and those were used to cut braces depending on the situation. They use a wire saw to divide existing damaged steel frames into individual components such as beams, columns and braces. They can also hold and cut the steel frame while lifting it with a crane.

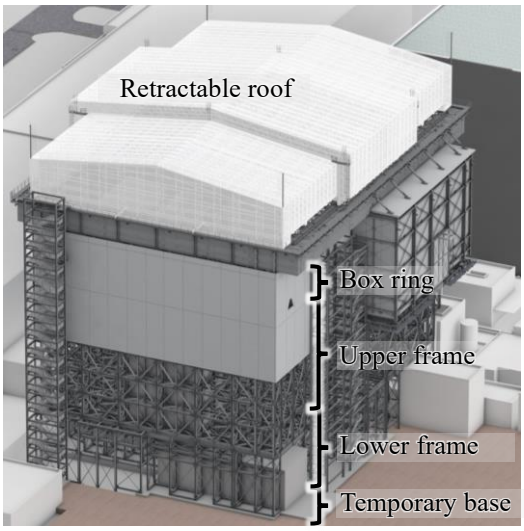


Image of large cover

Current status of Unit 1

E03

Construction status of platform structure for spent fuel removal from Fukushima Daiichi Nuclear Power Station Unit 2 and installation method of runway girder with reduction radiation exposure

Hiroshi Noda[1], Katsunori Enomoto[1], Tatsuya Nakamura[1], Tsuyoshi Saito[1], Daisuke Mukaiyama[1], Koki Sakamoto[1], Kazuki Shimizu[1]

Motohiro Taniyama[2], Junro Nakagoshi[2], Miho Miyazaki[2], Ippei Matsuo[2], Kihei Ogawa[2]

[1]Tokyo Electric Power Company Holdings, Inc.

[2]Kajima Corporation

Abstract

This paper presents current construction status of platform for spent fuel removal from Fukushima Daiichi Nuclear Power Station Unit 2.

Construction Status of platform structure

At Unit 2, fuel removal platform is being constructed on the south side of the reactor building. Four oil dampers are installed between buildings (existing reactor building and platform) to control the relative displacement of two buildings and to suppress deformation of platform. An opening was made in the south outer wall of reactor building, and the fuel handling machine will enter through platform to remove the fuel. Runway girder for fuel handling machine is installed across platform and the reactor building through an opening in the outer wall on the south side of the reactor building. Elastic bearing and spring-loaded oil dampers are installed between runway girder and the floor of the reactor building to reduce vertical response of runway girder.

Under the latest construction status, construction of platform and installation of runway girder have been completed, and fuel handling machine is currently being installed.

Installation method of runway girder with reduction radiation exposure

The radiation level on the operating floor of Unit 2 reactor building is extremely high, and workers can only work there for about 15 minutes a day. To reduce worker's exposure to radiation, it was necessary to adopt an installation method that would keep workers from entering the reactor building as much as possible. Runway girder is installed using the feed out method, eliminating work in the reactor building, where radiation doses are high.

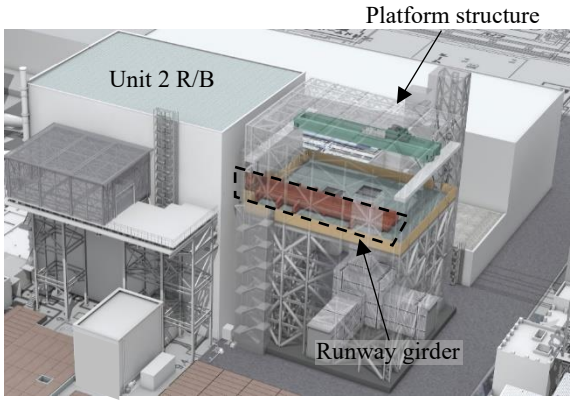
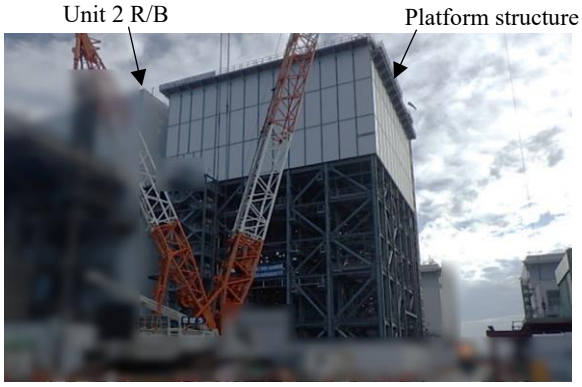


Image of platform structure



Current status of Unit 2

F01 Development of Optical Materials and Its Evaluation for the Radiation Dose-Rate Monitor under Ultra-High Dose-Rate III

Shunsuke Kurosawa[1,2], Chihaya Fujiwara[1], Yusuke Urano[1],
Ai Kaminaka[1], Kayo Sasaki[1], Akihiro Yamaji[1]
[1]Tohoku Univ., [2]Osaka Univ.

Abstract

We have developed a real-time monitoring system for high-dose-rate with a wide dynamic dose range using a novel red-emission scintillation material with both neutron and gamma-ray sensitivities.

1. Introduction

Mapping of high-dose-rate distribution in Fukushima Daiichi Nuclear Power Station is one of the first steps for decommissioning. Since conventional techniques are hard to monitor the rate due to the high-dose-rate condition of over 0.1 Sv/h, we have developed a fiber-type dose-rate monitor consisting of a red-emission scintillator. Scintillation photons are read with a photo-detector under a lower dose-rate thorough an optical fiber. On the other hand, Cherenkov and scintillation photons excited by radiations in the glass are expected to be observed as noises and these noises have generally emission wavelengths of below 550 nm. To discriminate the noise, we have developed a red-emission scintillator, Cs_2HfI_6 with an emission band of over 600 nm and other materials [1]. These materials have a gamma-ray sensitivity, while neutron measurement is also required. In this paper, we report novel scintillation materials with both gamma-ray and neutron sensitivities.

2. Methods

Li_2HfX_6 were grown by the vertical Bridgman-Stockbarger method, where X is Br or I. Such crystal samples were installed into the fiber-type dose-rate monitor. This monitor was demonstrated with a 20-m-long optical fiber and CCD spectrometer. We have evaluated the neutron reaction at Institute for Integrated Radiation and Nuclear Science, Kyoto University.

3. Results

Li_2HfBr_6 had an emission wavelength of around 570 nm excited by X-ray, which is longer than that of commonly used neutron scintillators such as Li-glass. The light output excited by thermal neutron excitation was estimated to be 52,000 photons per one thermal neutron. We succeeded in obtaining calibration data between neutron flux and scintillation intensity. Moreover, our gamma-ray and neutron scintillation materials with red or infrared emission bands have been improved, and we also report such novel materials.

4. Conclusion

This novel scintillator enables us to monitor high-dose-rate conditions with optical fiber, and we succeeded in demonstrating this monitoring system for neutron.

References

[1] S. Kodama and S. Kurosawa et al., APEX 13, (2020) 047002

F02 Research on omnidirectional neutron imaging system for ensuring safety in debris removal

Nishiki Matsubayashi[1], Tatsuo Torii[2], Yukihisa Sanada[3],
Shunsuke Kurosawa[4], and Miyuki Sasaki[3]
[1]Kyoto Univ., [2]Fukushima Univ. [3]JAEA, and [4]Tohoku Univ.

Abstract

We are developing an omnidirectional neutron imaging system to ensure safety during debris removal. The detector can measure the direction of incidence and intensity of neutrons, and can be used to indicate evacuation routes. In this study, the structure of the neutron detector and performance of the elements were investigated.

1. Introduction

In the debris removal for decommissioning of 1F, the shape of debris and surrounding environment may be changed, and neutrons may be generated. Since the debris are assumed to be unevenly distributed, an omnidirectional detector that can identify the direction of incident neutrons is required. In this study, we are developing the neutron imaging system based on the omnidirectional detectors for β/γ-rays [1]. In order to manufacture the detector, we investigated the response characteristics analysis of the system via Monte Carlo simulation and conducted the performance tests of the detector elements.

2. Overview of detection system

The developing omnidirectional detector is based on the FRIE (Fractal Radiation Imaging Elements) detector, a radiation imager for β/γ-ray measurement with a Sierpinski tetrahedron shape [1]. The FRIE for neutron (nFRIE) combines neutron scintillators and shielding materials (Figure 1). The detector elements consist of tetrahedral acrylics and thin LiF:ZnS scintillators, and the 16 elements are installed in the fractal structure with B_4C. To measure the neutron incident direction, the response characteristics to the direction were evaluated using a particle and heavy ion transport code system (PHITS). In the real-time imaging system, inverse problem analysis methods are used.

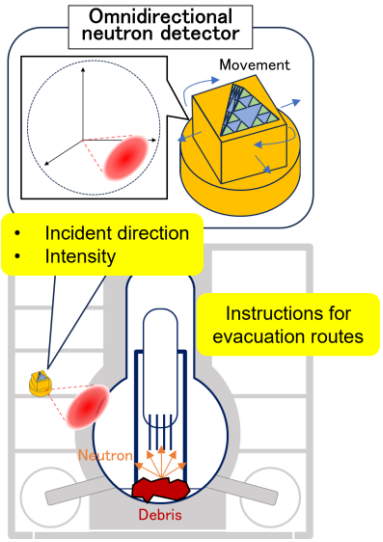


Figure 1. nFRIE

3. Results

The simulation using PHITS showed that the response patterns of the 16 elements differed depending on the neutron direction, and the performance tests showed that detectors were nearly insensitive to γ-rays. It was found that the system can estimate the neutron incident direction by the inverse problem analysis in real-time.

3. Conclusion

We proposed the omnidirectional neutron imaging system to identify the direction of incident neutrons. In the future, the detector will be fabricated and irradiation tests will be conducted at a reactor.

References

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F03 Evaluation of compliance with regulatory standards in decommissioning work using ETCC quantitative gamma ray imaging

T. Tanimori and A. Takada1,2,3 1 School of Frontier Engineering, Kitasato University, Sagamihara, Kanagawa, 252-0373, tanimori.toru@kitasato-u.ac.jp, 2 Graduate School of Science, Kyoto University, Sakyo-ku, Kyoto, 606-8502, Japan, takada@cr.scphys.kyoto-u.ac.jp 3 ERRAI Corporation

Abstract：

ETCC, which has achieved linear imaging of gamma rays for the first time in the world, will enable non-destructive testing during decommissioning work. ETCC's technology has been selected twice by the Ministry of Education, Culture, Sports, Science and Technology's "Problem-Solving-type Decommissioning Research Program" and has been proven through experiments conducted at the Fukushima Daiichi Nuclear Power Plant.（Fig.1）

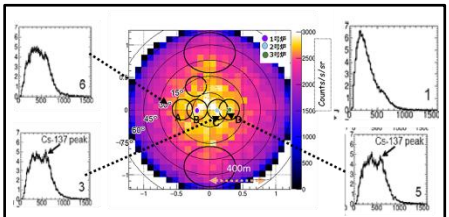

Fig1: Wide-area gamma ray imaging of Fukushima Daiichi Nuclear Power Plant by ETCC

Introduction：

To explore MeV gamma-ray astronomy, we developed the world's first camera ETCC which is capable of taking linear images of Compton-scattered gamma-rays [1], and have conducted two astronomical observations using JAXA balloons [2]. Also, we have used this technology for the nuclear energy with a number of achievements. ETCC (Fig. 2) can measure both the direction of recoil electrons with gaseous Time projection Chamber (TPC) and scattered gammas with Scintillator pixel arrays , and then solves the Compton scattering equation completely. Thus, we could uniquely determine the direction of gamma-rays, and realized the world's first two-dimensional PSF definition and linear imaging as in optics [1,4]. ETCC is capable of several degrees of PSF.

The image data acquired by ETCC is linear, so it is possible to use image processing technology used for visible light imaging. For example, by installing multiple ETCCs, it is possible to acquire stereo images, enabling the introduction of non-destructive testing in decommissioning work.

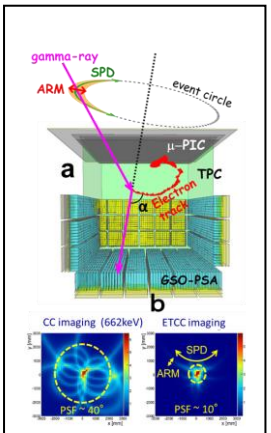

Fig. 2 Schematic view of ETCC, and images of point sources of C.C. and ETCC

Reference

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F04

Triple modular redundant RISC-V processor and the test system for radiation

Masato Isobe, Minoru Watanabe, and Nobuya Watanabe
Okayama University

Abstract

Under a strong radiation environment such as decommissioning a nuclear plant, processors must have high-radiation tolerance. Currently available processors are always weak for radiation and are easily broken by radiation for a short period. Therefore, we have been developing a triple-modular-redundant processor to increase the radiation tolerance. This paper presents the implementation of triple modular redundant (TMR) RISC-V processor and the test system for radiation.

1. Research Background

Processors must have soft-error tolerance. In addition, the life-time of currently processors under strong radiation environments such as decommissioning a nuclear plant must be extended. So, we have introduced triple modular redundancy (TMR) for RISC-V processor in order to increase the total-ionizing-dose tolerance.

2. TMR RISC-V Processor

Fig.1 shows the block diagram of the TMR RISC-V processor. The TMR RISC-V processor consists of a program counter, an instruction memory, a control unit, a register-file, an arithmetic logic unit (ALU), and a data memory. All modules are triplicated. The TMR RISC-V processor has been implemented onto a Cyclone-V FPGA. The configuration data was generated from Quartus software. The maximum operating clock frequency was 64.82MHz. The overall resource usage is 45%. 14,369 ALMs and 52320 FFs were used.

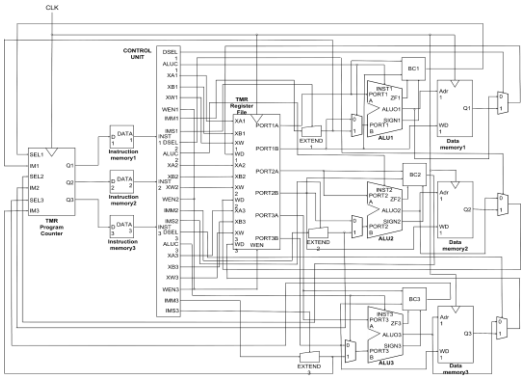

Figure1. TMR RISC-V processor design

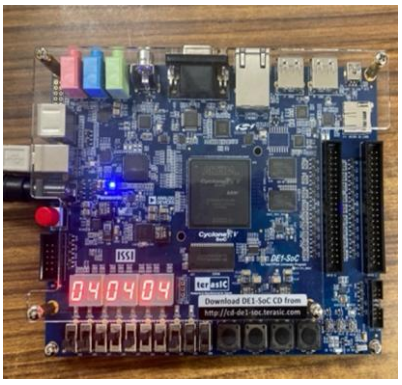

Figure2. processor implementation

3. Test system for radiation

The radiation test for soft-error tolerance was done by using 4kBq Americium. The test system monitors whether any soft-error on FF occurs or not. In the FPGA, there are two types of errors on configuration memory and FFs. The system can classify the two errors.

F05

Operating range evaluation of optically reconfigurable gate array VLSI with a parallel configuration architecture

Ryosuke Ogawa, Minoru Watanabe and Nobuya Watanabe
Okayama University

Abstract

Under a high-radiation environment such as nuclear power plants and space, integrated circuits are permanently damaged by radiation. In an optically reconfigurable gate array VLSI, the programmable gate array can be reconfigured to avoid damaged hardware parts and to use the rest non-damaged parts [1]. Therefore, the optically reconfigurable gate array VLSIs have 1 Grad total-ionizing-dose tolerance. In this paper, we present the operating range evaluation results of the optically reconfigurable gate arrays that can be configured in perfectly parallel.

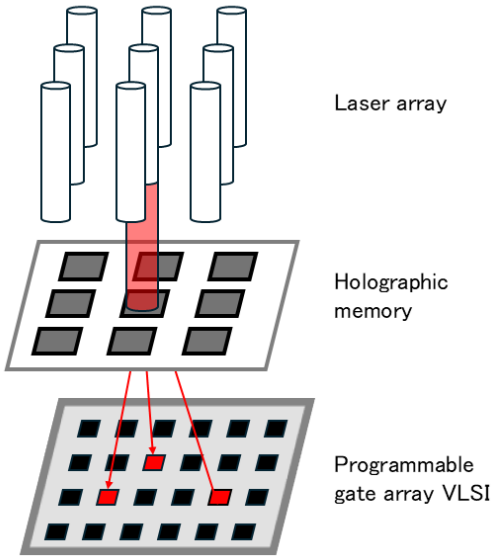

Figure 1. An optically reconfigurable gate array.

1. Optically reconfigurable gate array VLSI with a parallel configuration architecture

The optically reconfigurable gate array VLSI consists of a number of photodiode circuits. The photodiode circuit consists of a transistor, an inverter, and a photodiode. The photodiode circuits on optically reconfigurable gate array VLSIs can be reconfigured individually so that a partly broken programmable gate array can be used continuously.

2. Operating area evaluation of optically reconfigurable gate array VLSI that can be fully parallel configured

A three-input AND circuit was implemented onto an optically reconfigurable gate array to measure the relationship between necessary optical power and the voltage range to control photodiode current. As a result, the operating voltage range and necessary optical power were 1.799 V-1.896 V and 46.8 μ W/mm^2 – 1,605.1 μ W/mm^2.

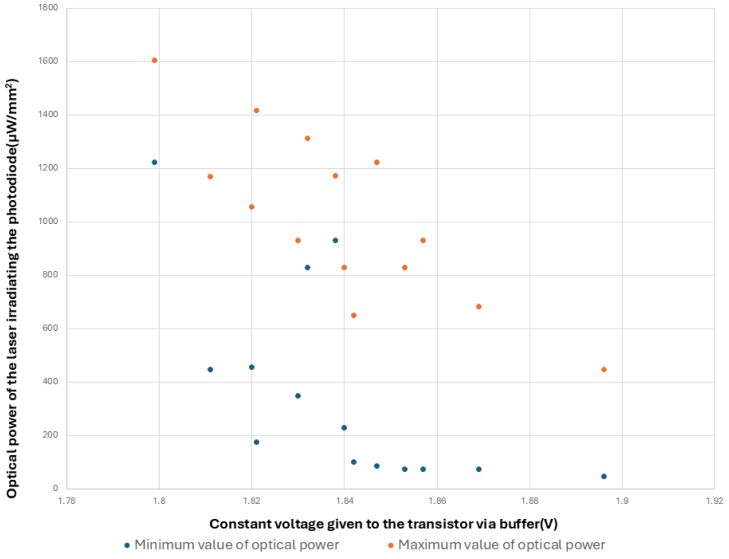

Figure 2. The operating area

References

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F06

Evaluation of soft error tolerance by implementing Quintuple Modular Redundancy

Shuto Shiba, Minoru Watanabe and Nobuya Watanabe

Okayama University

We have been developing an optically reconfigurable gate array (ORGA) VLSI. An ORGA consists of three components: a laser array, a holographic memory, and a gate array VLSI. Circuit information is stored in the holographic memory and is programmed in parallel onto the programmable gate array VLSI. The ORGA has an advantage that its soft error tolerance is higher than that of SRAM-based FPGAs configured with a serial bus.

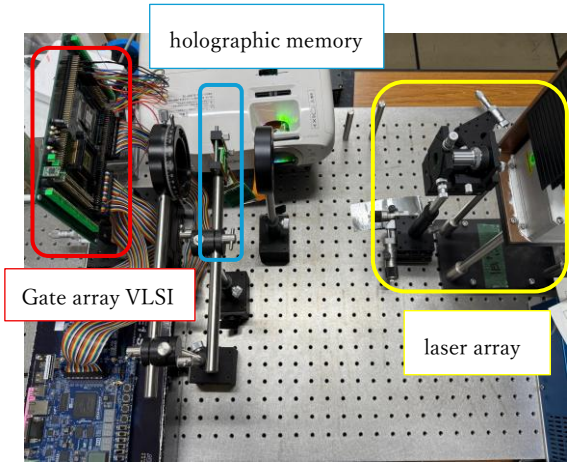

Figure1. Optically reconfigurable gate array.

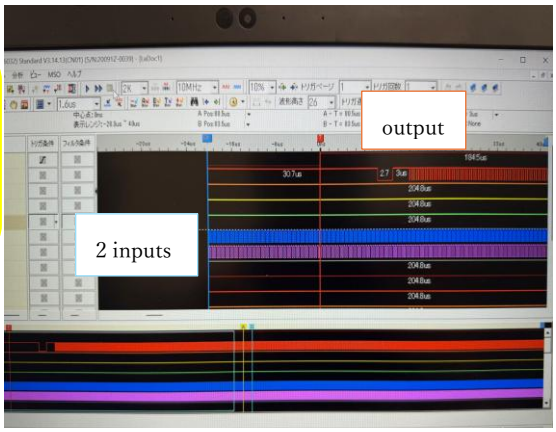

Figure2. Implementation of an OR circuit.

To increase the soft-error tolerance, always, Triple Modular Redundancy (TMR) for a main module has been implemented onto the ORGA. Three identical circuits and majority voting circuits are implemented. In this case, even if a soft error occurs in one module, correct output can be obtained from the results of majority voting operations. However, if a module is permanently broken, the reconfiguration must be executed. Of course, although a TMR detection circuit can detect a failure module, under a high-radiation environment, a correct detection without any soft-error is difficult. Therefore, to detect which module is broken by radiation, in this study, we have introduced Quintuple Modular Redundancy.

LA-UR-25-25812

F07 Evaluation of Neutron Detection Technology and Analysis Techniques to Support Fukushima Daiichi Decommissioning

D. Henzlova, N. Cannon, J. Hutchinson, G. McKenzie, J. R. Moussa, M. Nelson, R. Weldon
Los Alamos National Laboratory, Advanced Nuclear Technology Group, Los Alamos, USA

Abstract

Decommissioning efforts and associated fuel debris retrieval from the damaged Fukushima Daiichi reactor units require robust methods to monitor and assure subcriticality. These include adequate detection technologies capable to withstand high gamma radiation conditions within the units; as well as analysis methods capable to provide robust signatures to assure agile criticality monitoring in situation where material distribution is changing. This poster will present experimental and analytical efforts focused on evaluation of neutron-based technologies and development of real-time analysis using state-of-the art capabilities available within the 1F Fuel Retrieval and Monitoring Experiments (1FRAME) project.

1. Introduction

1FRAME project was recently launched in the United States as a collaborative endeavor between US, Japan, and France to support Fukushima Daiichi fuel debris retrieval efforts through strategic cooperation and leveraging of existing capabilities. One aspect of the 1FRAME project focuses on assessment and optimization of neutron detection techniques and the underlying analysis methodologies to specifically address unique conditions within the Fukushima reactor units. These efforts leverage diverse experimental capabilities (National Criticality Experiments Research Center and instrumentation calibration facilities) as well as in-depth experience with neutron diagnostics tools and neutron noise analysis techniques from variety of subcritical and critical experiments.

1. Neutron Techniques Evaluation and Development

The experimental efforts within the 1FRAME project include evaluation of neutron detection technologies and associated signal processing electronics for viability in high gamma dose environments and ability to provide robust neutron signatures. Range of experimental campaigns are planned to evaluate radiation hardness of electronics components and to assess neutron detection performance in high gamma dose and mixed neutron/gamma environments representative of Fukushima Daiichi conditions. Initial evaluations currently underway focus specifically on radiation hardness of next-generation signal processing electronics, which has been recently developed for use with a range of proportional counters.

To enable a reliable criticality monitoring capability for Fukushima fuel debris retrieval efforts, detection systems must be accompanied by a robust analysis method capable to provide real-time criticality monitoring to assure safe operating condition while nuclear material is being removed and/or repositioned. 1FRAME efforts focus on development and implementation of such real-time monitoring capability using existing neutron noise analysis tools. Additionally, recently developed advanced analytical techniques enabling source localization and distribution monitoring are evaluated and optimized for Fukushima decommissioning needs. Both experimental and analytical efforts are supported by particle transport modeling and simulation.

3. Conclusion

1FRAME project leverages state-of-the-art experimental capabilities and broad experience base with neutron noise measurements and analysis methods in support of Fukushima Daiichi decommissioning efforts. This work presents an overview of these experimental capabilities and facilities along with the results of initial irradiation tests and progress update on development of real-time criticality monitoring and source localization methodology.

H01

SIAL®: Geopolymer solidification technology approved by Slovak / Czech Nuclear Authority

Marcela Blazsekova, Milena Prazska, Maros Juraska and Marek Meciar , Amentum Slovakia s.r.o.
Hisashi Mikami , Kazutaka Hirata and Nobuyuki Sekine , Fuji Electric Co.,Ltd.

Abstract

We present the features and the performance records of SIAL® geopolymer solidification technology is licensed by both the Slovak (ÚJD SR) and Czech Nuclear (SUJB) regulators, and the technology has been used successfully for 20 years. Recently, geopolymer has been noted as an immobilization technology and which shows potential of immobilizing sludge and slurry generated by treatments of contaminated water at Fukushima Daiichi Accident. Most recent research on the advanced SIAL® geopolymer has focused on a injecting application into RPV and PCV for stabilization of fuel debris or stopping of water leakage.

1. Introduction

The Nuclear Power Plant (hereinafter called NPP) Unit A1 located in Jaslovske Bohunice, which was completed in 1972 and had been operated for 5 years until two accidents happened in 1976 and 1977. After the second accident (INES level 4), NPP Unit A1 was permanently shut-down for decommissioning. Damaged fuel assemblies and claddings in the accidents caused contamination of strontium-90, caesium-137 and transuranic. As a result of a long-term corrosion of barrier's materials, highly contaminated sludge were accumulated, and the waste could not be effectively immobilized with using conventional methods such as Cementation or Bitumen treatment due to negative impact on physical-chemical properties and high specific activity (caesium-137) of the waste. This challenge led to developing SIAL® solidification technology. Today, SIAL® is proven and widely used for on-site solidification of radioactive waste streams such as sludge, resins, sorbents and organic liquids. This is directly applicable to the conditions at Fukushima Daiichi as well as other Japanese NPPs where the waste streams are not well understood.

2. Feature

SIAL® geopolymer can provide efficient and practical on-site treatment of radioactive waste streams at room temperature. The equipment used to deploy SIAL® solidification technology is also modular, flexible and versatile. It can encapsulate waste streams quicker than Cementation, and can be applied under water. SIAL® solidification technology can realize higher compressive strength and lower leachability compared to Cementation, and posing a low fire risk and excellent physical stability in the presence of frost and water (no distortion or cracking).

Figure 1 200L Indrum kneading machine and SIAL® solidified body of resin

Figure 2 Areva sludge and Fe and Carbonate slurry waste streams cross section observation

3. Performance Record Example

About 3×10^6 kg of radioactive waste streams (resins, sludge and crystalline borates) is successfully immobilized using SIAL® . This comprehensive scope of works started with licensing processes, solidification, and then were followed by decontamination and cleaning of the workplace post cleanup and transports of all equipment to off-site.

4. Injecting application

Most recent research on the advanced SIAL® geopolymer has focused on a injecting application for stabilization of fuel debris or stopping of water leakage. Pilot-scale trials have been proven that it is possible to apply to the RPV or PCV.

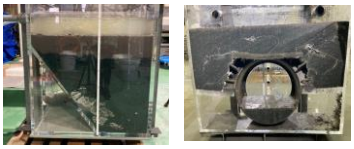

Figure 3 SIAL® matrix with sandbag solidified under water and successful stopping leakage water

H02 Decommissioning research conducted by JAEA (3) Radioactive waste management initiatives

Mitsuru Sambongi, Azusa Ito, Yoshikazu Koma, Takeshi Osugi,
Takashi Okada, Kazuki Iijima
Japan Atomic Energy Agency

Abstract

This poster introduces interdisciplinary R&D conducted by Japan Atomic Energy Agency (JAEA) on the characterization, storage, processing and disposal of the solid radioactive waste generated by the TEPCO Fukushima Daiichi Nuclear Power Station (1F) decommissioning, with an example of R&D conducted in the storage for the volume reduction and recycling of 1F radioactive metal waste.

1. Introduction

A significant amount of solid waste with various radioactive properties has been generated by the 1F decommissioning, and it is an important issue to consider how to store, process and dispose the waste safely and practically while taking into account of the waste stream. To solve this issue, JAEA has been carrying out the R&D in close cooperation with each project of characterization, storage, processing and disposal.

This poster introduces the interdisciplinary R&D conducted in each project, with the example of R&D on the storage.

2. Interdisciplinary collaboration of each project to manage the 1F solid waste

It is important to carry out the R&D in close cooperation with each project of characterization, storage, processing and disposal to attain the results for safe and practical 1F solid waste decommissioning. Therefore, we clarified the following for each project: items for consideration, project status, consideration and information flows, and feedback.

3. Approaches to the R&D on volume reduction and recycling by the melt refining

An installation of metal melting facility is planned in 1F site to reduce the volume of metal waste with an effect of decontamination, which promote recycle use limited to 1F of the material. For this purpose, radionuclide partitioning behavior between metal and slag during the melt refining process and a verification method of the processed metal are under development, specifically, the inventory estimation method of the metal waste, the investigation of radionuclide migration behavior during the melt refining process, the study of radionuclide migration behavior by experimental melting, the selection of important radionuclides that shall be evaluated prior to recycle the processed metal, and the strategic planning for the selection .

Acknowledgement

This study was performed under the subsidy program “Project of Decommissioning, Contaminated Water and Treated Water Management (Research and Development of Processing and Disposal of Solid Waste)” conducted by the Ministry of Economy, Trade and Industry of Japan.

H03

Design and On-site Decommissioning Support to the Bohunice Nuclear Power Plant, Slovakia

Nicole Cain, John Maddison , Amentum (formerly Jacobs)

Abstract

Amentum (as Jacobs) have provided extensive waste management and decommissioning support to the Bohunice Nuclear Power Plant (NPP) in Slovakia for the first ever dismantling of a VVER-440 nuclear reactor. The work involving multiple phases has included the underwater dismantling and segmentation of reactor coolant system components, the design and provision of measuring equipment for radiological characterisation, and the delivery of a bespoke waste packaging and transportation system. Amentum are opening an office in Futaba to bring this type of experience directly to the Fukushima decommissioning challenges.

Introduction

As part of the dismantling, segmentation and packaging of the reactor internals of the Bohunice V1 NPP, Amentum supported the radioactive waste management of the reactor in a variety of different ways.

2. Project Delivery Activities

2-1. Dismantling

The reactor coolant system components were removed from their operational position and placed into two new Wet Cutting Workstations (WCWs) constructed by Amentum. Here we undertook the dismantling and segmentation of several auxiliary systems.

Figure 1. Basket Handling

2-1. Sampling

Sampling of activated components, with high dose rates of up to 1000Gy/h, was undertaken using remotely operated equipment. This activity took place in a confined space and required the separation of contamination from activated components. Amentum developed the sampling methodology for this task.

2-2. Characterisation

Amentum undertook analysis of the samples, determined suitable waste volumes and confirmed the waste package form, including the calculation of appropriate shielding thickness for the sample packaging.

2-3. Waste Handling

Amentum utilised remote handling technologies to package larger waste volumes into drums or box pallets, including the characterisation of the drums. This involved innovations which enabled the measurement rate to be increased, optimising the process.

2-4. Waste Transportation

A complete Basket Transfer Station was designed, developed and operated by Amentum, ensuring the safe onward transportation of the Waste. This included appropriate shielding and mechanical handling of the baskets from the bottom of the pool. These baskets were subsequently transferred to specially designed transportation containers for onward management.

3. Conclusion

Amentum played a key role in the delivery of end-to-end dismantling and waste management of the WWER-440 reactor at the Bohunice Nuclear Power Plant, demonstrating a great breadth of capability and experience relevant to the decommissioning challenges at Fukushima Daiichi.

H04 Radioactive Scrap Metal Recycle, Japanese Demonstration.

Colin Austin, Tomoaki Fujikawa and Makoto Kikuchi
Energy*Solutions*, Charlotte NC. USA

Abstract

1. Introduction

Energy*Solutions* (ES), founded in 2005, but with legacy dating back to the establishment of Envirocare and the original commercial US LLW Disposal in 1990, was established by acquiring companies both from the United States (US) and from the international market with market leading project delivery and technology to enable provision of the full value chain of nuclear backend service mainly in the areas of radioactive waste management, nuclear facility D&D and radioactive waste disposal. The company can bring together over 50 years of global experience, which provides the full suite of nuclear services in an integrated, often unique solution, for their customers across the globe. Notably in the US, ES have been involved in majority of completed D&D projects, including the La Crosse, SEFOR, and Zion sites which were fully managed by the company as commercial D&D business. One of the next major challenges is to complete D&D work at TMI-2.

2. Resource not Waste

Since the early 90s, ES have been accepting over 7,500t of radioactive contaminated metals from the international market to recycle for beneficial reuse, mainly to produce shield blocks that would be re-used in the nuclear industry. The key here is two-fold; no material would be disposed in the US, and concurrently, no material would need to be returned to the customer through this beneficial reuse process and that this solution can support the client create space on site. After close working relationships with the Japanese nuclear utilities, ES is now recycling Japanese spent fuel casks, into useful product, that have been delivered to ES's Memphis recycling facility this January and following decontamination and dismantling have been melted and repurposed for beneficial reuse at the company's Bear Creek Facility in Oak Ridge TN. This is the 1st shipment from Japan under the new system in law, introduced on January 11th, 2023, and it is a major achievement made by the industry to demonstrate that there is an outlet for recycle and beneficial reuse of these materials. This message is now shared and accepted globally, resulting in contracting vast volume of new metals from Europe just in these past few months, exceeding the total amount of metals ES has ever recycled from the international market. This has great benefits in carbon foot-print reduction through metals recycle, preservation of important disposal site capacity and generating much needed space on D&D sites by removing and recycling stored material.

3. Conclusion

ES, with its rich experience in D&D, is now re-illustrating the international business strategy to design D&D around recycling, not just with the metals, but also with assets such as radio nuclides that can be harvested to be re-used as radioisotopes. Marubeni Utility Services (MUS), as ES's agent for the metals melt business, believes that this is going to be a paradigm shift for the D&D to become recycle projects, not a waste management project, and is very excited to work together through this phase to establish a new standard for Japan and the world.

H05 Transformational Technology Driving the Paradigm Shift From Nuclear Waste Disposal to Valuable Resource Recycling.

Tim Milner, Colin Austin and Makoto Kikuchi
Energy*Solutions*, Charlotte, NC, USA

Abstract

1. Introduction

Energy*Solutions* (ES), employs over 50 years of global decommissioning, waste management and disposal experience to drive innovation from inception to project delivery. In the US, ES has safely and successfully executed the majority of completed D&D projects, including the La Crosse, SEFOR and Zion sites, which were fully managed by the company as a commercial D&D business. One of the next major challenges is to complete D&D work at TMI-2. Post-accident, immediate remediation and gross defueling of TMI-2 was completed in the 1990's. Today ES is completing the removal of the hard to remove post-accident fuel bearing material and remotely decontaminating, dismantling, and decommissioning the reactor vessel, primary loop components and associated infrastructure.

2. Transformational Technology

ES with its deep history and capability in nuclear waste management and disposal has embarked upon a transformation of the nuclear back-end. Applying innovative technologies that shift the paradigm from the accept notion of redundant plant and components being nuclear waste to a new understanding that these materials represent valuable resources for sustainable recycle. At the vanguard is Energy*Solutions*' new entity SUVA, who are bringing this capability to new international markets. Using our own projects to demonstrate this paradigm shift ES is engaged in deploying a suite of innovative technology at TMI-2 including, advances in electrokinetic filtration for spent fuel bearing material, targeted chemical decontamination for preferential dissolution of spent fuel bearing material, advanced liquid waste treatment with new elutable ion-selective media for selective harvesting of key radionuclides for beneficial reuse, advanced thermal volume reduction and stabilization techniques and a suite of remotely deployable dismantling techniques, informed by radiation dose visualization and point cloud digital twins, to guide and update the decommissioning process. The recycle process is completed by ES metal melt and recycling processes at Bear Creek in Oak Ridge, TN, where innovations in additive manufacturing to repurpose recycled metals into new products for use in the nuclear industry are being developed.

3. Conclusion

ES with its rich experience in D&D and nuclear waste management and disposal is applying its knowledge and expertise to create value from what was traditionally referred to as nuclear waste. In doing so, this preserves strategically important radioactive waste disposal site capacity via diversion and resource recovery and reduces carbon footprint by repurposing and reusing metals avoiding the considerable greenhouse gas emissions from metal ore processing and steel manufacture. Additionally, providing a source of radionuclides harvested for beneficial use from what was once considered waste, to drive forward, radio-medicine, instrumentation, space flight and agriculture. This paradigm shift from waste to resource further enhances the credibility and vital role the nuclear industry will play in a sustainable energy future and combating climate change.

I01 3D Visualization of air-dose rate of working spaces by Digital Twin

Kenji Koizumi, Masahiro Suzuki, Kazuhisa Aoki, Susumu Yamada, Minsik Kim,
Kenta Suzuki, Fumiaki Abe, Masahiko Machida, Koji Okamoto
Japan Atomic Energy Agency

Abstract

In the decommissioning of TEPCO's Fukushima Daiichi NPP (1F), it is crucial to improve the environment of working spaces inside the reactor building (R/B) as the fuel debris removal works go into full-scale levels. Among various environmental improvement issues, one of the most essential ones is to reduce the exposure of workers as much as possible by utilizing advanced safety planning and designing tools. Thus, JAEA has so far developed a digital software tool to reveal 3D distributions of air dose rates and perform virtual simulations to reduce worker's exposure inside working places.

In the developed tool system, a core part is to inversely estimate radiation-source spatial distributions and their magnitudes even in limited monitoring results using a machine learning technique called LASSO [1]. By measuring the point cloud data and air dose rate data using measuring devices mounted on remote-controlled robots, 3D distributions of the obtained contamination can be displayed, and decontamination evaluation and safety analysis for worker exposure reduction can be performed without radiation exposure on virtual digital space.

1. Introduction

The most fundamental process to avoid human exposure is to reveal radiation source distributions and resultant 3D distributions of air dose rates inside target workplaces. However, such attempt has been regarded as one of the most difficult mathematical problems called as an ill-posed one, since the monitoring is severely limited according to widely spread radiation distribution. Then, we have strongly paid attention to a solution using the machine learning technique called LASSO as a candidate scheme to overcome such ill-posed problems. We have developed a system (3D-ADRES-Indoor) that estimates the source and dose rate distribution from limited on-site information (structural data and air dose rate data). So far, we have performed an evaluation test of the scheme in 1F Unit 5, and have confirmed that the evaluation scheme performs without any problems. Based on these results, we further confirmed that it can be applied to real complex sites such as 1F through verification tests on 1F Units 2 and 3.

2. Verification Tests inside 1F Unit 2 and 3

This section presents the contents of the test processes inside 1F Unit 2 and 3 performed in 2024. We employed remote-controlled systems composed of a four-legged robot called SPOT produced by Boston Dynamics Co.LTD to obtain point cloud data and air dose rate data. Based on the obtained data, we examined the following processes to inversely estimate source radiation distributions and calculate resultant 3D distributions of air dose rates,

(1) Making 3D mesh models from point group data in a rapid manner to execute the LASSO scheme soon after the data accumulations,
(2) Together with the above mesh models, estimating radiation source distributions based on air dose rate measurement data using LASSO,
(3) Calculating 3D distributions of air dose rate from obtained radiation source locations and magnitudes,
(4) The obtained 3D air dose rate distributions are evaluated by detailed monitoring results measured for the purpose of the evaluation of the estimated results.

3. Results in Tests inside Unit 2 and 3

In a selected area on the first floor of Unit 2, point cloud data and air dose rates at multiple location sites were measured as shown in Figs. 1 (a) and (b). Based on these measurement data, we inversely estimated the pollution distribution as shown in Fig. 1(c). By comparing the air dose rate distribution evaluated from the inversely estimated source distribution with the actual monitoring results, we can identify the contamination source distributions with high accuracy even for complex structures such as 1F reactors, and demonstrate that it is possible to estimate 3D dose rate distributions inside target working spaces. By applying such digital analysis, it is possible to do safety checks on various work procedures in virtual space without any real radiation exposure as shown in Figure 2.

(a) Point cloud data (b) Air dose rate data (c) Estimated dose rate distribution

Fig.1 Evaluation Tests in 1F Unit 2

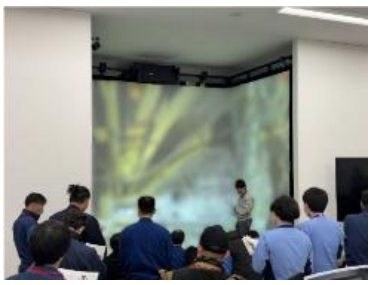

Fig.2 Safety study in virtual space using NARREC's VR system

Acknowledgements

This work was carried out under a subsidy program of "Project of Decommissioning, Contaminated Water and Treated Water Management", entitled "Development of Technologies for Work Environmental Improvement in R/B". We are indebted to any other members of the project and NARREC extensive cooperations.

References

[1] S. Yamada et al., "Selection method for observation points using Bayesian LASSO at estimating radiation source distribution from air dose rates", Joint International Conference on Supercomputing in Nuclear Applications + Monte Carlo , (2024)

I02 Decontamination & Decommissioning Technologies for the Civil Nuclear Industry

Michael J. Anderson, Victoria E. Anderson-Matthew, Kazushi Watanabe, Sarah A. Peirce

Innovative Physics Limited

Abstract:
The nuclear industry faces numerous challenges in decommissioning, including improving efficiency and safety while reducing costs. Advanced technologies, including robotics, sensors and artificial intelligence, have the potential to address these challenges by automating hazardous tasks, improving accuracy and reducing human error.

Introduction:
Below outlines some examples of technologies that Innovative Physics Limited (IPL) have developed.

Sort & Segregation of Nuclear Waste

Utilising advanced computer vision, machine learning, and robotic technology to automate the sorting and segregation of nuclear waste. The system accurately identifies and sorts different types of debris while improving efficiency, reducing costs, and enhancing safety. Notably, the automated system eliminates the need to expose workers to harmful radiation. The future potential of this technology is significant as it can be applied to other industries, such as waste management, mining, and construction.

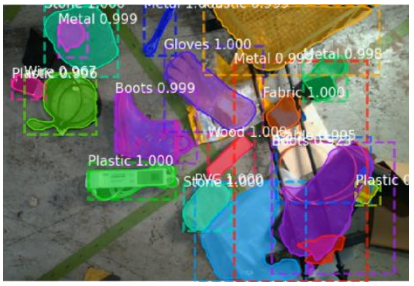

Figure 1: Object and Material Identification

Gamma Imaging Systems

Decontaminating an area containing nuclear waste is difficult due to the intangible nature of radiation. Working closely with Japanese partners, IPL designed and developed a gamma imaging system capable of showing "hot spots" of radioactivity. The systems provide an image/video of a large area, allowing workers to quickly and remotely observe where radiation hot spots are located and determine, within minutes, the radioisotope being emitted.

Figure 2: Gamma Imaging

Neutron Detection

Decommissioning planning requires a comprehensive mapping of the radiological environment. Importantly, the location of the fissile material is required, i.e. the neutron field. This allows path planning for removing such material while avoiding criticality events. Custom solid-state neutron detectors using a semi-conductor deposited with Boron-10 (B10), which show a high gamma radiation tolerance and gamma rejection ratio (Co-60, Cs-137up to > 1/106cps/cm2s) to enable monitoring of neutron flux in highly radioactive environments, such as criticality monitoring, emergency management, core monitoring. The novel neutron detector architecture is modular and thus can be integrated into many applications.

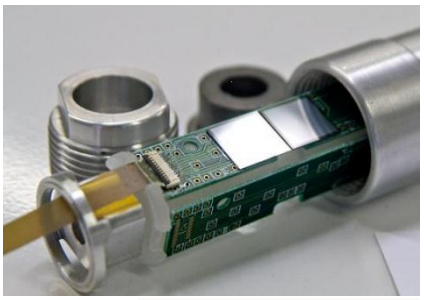

Figure 3: Semi-Conductor Neutron Detector

Very Low-Level and Low-Level Waste Management

To measure the surface contamination (gamma dose rate) and the isotope of radioactivity. Large scintillators and the relative movement of sensors and objects are used to identify the location of radioactivity. The system uses Time Delay Integration (TDI) techniques to provide additional security and variable speed detection.

The nuclear industry confronts challenges in decommissioning, striving for efficiency, safety, and cost reduction. Advanced technologies like robotics, sensors, and AI offer solutions by automating tasks, enhancing accuracy, and minimizing human error.

In sorting and segregating nuclear waste, computer vision, machine learning, and robotics automate processes, improving efficiency, reducing costs, and ensuring safety by eliminating worker radiation exposure. The technology's potential extends beyond nuclear industry applications to waste management, mining, and construction.

Gamma imaging systems, developed in collaboration with Japanese partners, detect radiation hotspots, aiding in decontamination efforts by providing remote observation and identification of radioactive materials.

For decommissioning planning, mapping the radiological environment is crucial, especially locating fissile material. Custom solid-state neutron detectors offer high tolerance to gamma radiation, enabling monitoring of neutron flux in highly radioactive environments for criticality monitoring and emergency management.

Very low-level and low-level waste management involves surface contamination measurement and radioactivity isotope identification using large scintillators and TDI techniques for enhanced security and variable speed detection.

J01

Waste Management Symposia: The Annual Phoenix Conference Exchanging Knowledge from Around the World

Kazuhiro Suzuki[1], Takashi Mitsui[2] Katsunori Koarai[3], Satoshi Okada[4], Mariko Nishizawa[5]
[1] WM Symposia, Inc. [2] IHI Corporation, [3] Createc East-Asia KK,
[4] Hitachi-GE Nuclear Energy, Ltd., [5] LITERA JAPAN

Abstract

NPO WM Symposia's annual Waste Management (WM) International Conference attracts thousands of registrants from around the world and is widely regarded as the premier international conference for the management of radioactive waste and related topics, such as facility decommissioning, environmental cleanup, used fuel and nuclear materials management, and long-term environmental stewardship. WM Symposia is dedicated to providing educational assistance to support our value proposition of empowering minds. WM believes in Education and Mentoring to prepare the next generation of nuclear waste professionals with use of funds from the conference.

1. Introduction

The WM2026 Conference will be held MARCH 8 -12, 2026 at the Phoenix Convention Center in Phoenix, Arizona. Conference theme is "**Efficient and Innovative Nuclear Materials and Technology Solutions**". WM2026 will feature over 500 papers and more than 80 panel discussions in over 200 technical sessions, complemented by nearly 200 exhibiting companies, the industry's largest. WM2026's Featured Country - Finland and Featured US DOE Site - Hanford, Washington. Sessions on decommissioning of Fukushima Daiichi Nuclear Power Station is also planned.

2. Poster

The poster provides Conference details and describes Technical Panel, Poster and Oral Sessions, Exhibitor, Student and Sponsorship program, as well as the opportunity to network with over 3,000 industry specialists and managers. The conference cross-cutting theme will highlight how the rapidly evolving digital world is making transformational changes to the worldwide radioactive waste management, nuclear industry, and clean-up sectors. The conference will showcase how the digital world is leading to achieving more efficient operations, improved human-machine interactions, increased safety, and enhancement of data management and analytics. In addition, WM Symposia's Education Assistance Spectrum will be shown on the poster.

3. Conclusion

The Conference promotes, among Japanese and professionals from around the world, a broad exchange of knowledge in 12 Technical Tracks, including technologies on operations, safety, security & safeguards, fuel cycle, waste management, decommissioning and dismantling, environmental remediation, communication, advanced nuclear reactors and STEM education, etc.

The deadline for submittal of Abstracts for WM2026 is August 22, 2025. The submitted abstracts will be reviewed by PAC members, and selection will be made at Program Development Meeting to be held in Arizona on September 7-9.

WM2026 Registration will open in September, and registration rates will be released during registration opening.

References: www.wmsym.org
www.t-g-consulting.com

J02 Decommissioning research conducted by JAEA (2) Virtual reality comes to debrisEye a new step for decommissioning support

Kenta Shimomura[1], Takuya Yamashita[1], Eiichi Nagai[2]
[1]Japan Atomic Energy Agency (JAEA), [2]Prometech Software, Inc.

Abstract

Understanding the complex internal conditions of the Fukushima Daiichi Nuclear Power Station (1F) requires more than individual pieces of data. To address this challenge, the interactive visualization tool debrisEye was developed [1, 2], allowing users to explore a 3D model of the plant with overlaid investigation data. Building on this foundation, we have implemented a virtual reality (VR) extension to provide a more immersive and intuitive experience, aimed at enhancing spatial understanding and supporting decommissioning planning.

1. Introduction

A large volume of data has been collected to support understanding of conditions within the Fukushima Daiichi Nuclear Power Station (1F). However, examining these data individually makes it difficult to grasp the overall situation. To overcome this, JAEA developed debrisEye, an application that overlays investigation results and analysis data onto a 3D model of the plant. To further enhance spatial comprehension, this system has been extended with virtual reality (VR) functionality.

2. Integration of debrisEye with VR

In the VR-enhanced version of debrisEye, the existing 3D model is presented within an immersive environment. To increase realism, dynamic lighting effects responsive to user movements have been implemented. This creates a more intuitive and engaging experience (see Figure 1).

Figure 1. debrisEye VR screen

3. Conclusion

Integrating VR technology into debrisEye has significantly improved spatial understanding of the 1F site. This intuitive visualization is expected to contribute to increased efficiency and rationalization of future decommissioning work.

References

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