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Development of Small and Medium-Sized Robotic System for Nuclear Emergencies and High-Radiation Scenarios

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CONTENTS

01 Background

Background

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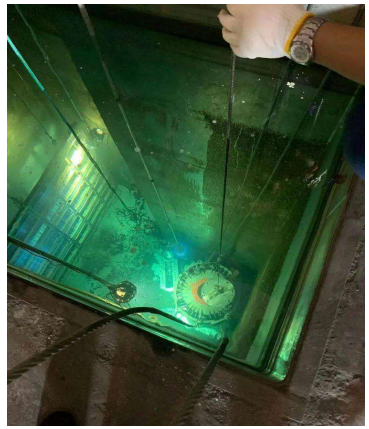
Nowadays, the nuclear industry is developing rapidly, covering such aspects as the field of nuclear power, nuclear material production, and decommissioning management. Along with the development of the nuclear industry, nuclear safety issues have become particularly important.

Cyclotron

Isotope Production



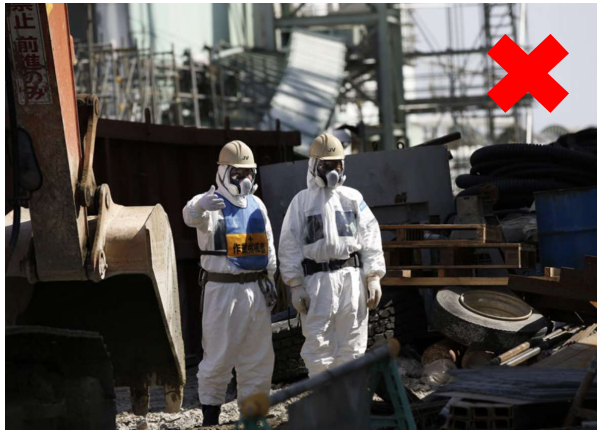
irradiation facility

Nuclear and Radiation Safety, Nuclear Emergency Response, Nucleasecurity.....

Background

source stuck incident

Fukushima Daiichi Nuclear Disaster



In a **low-dose-rate** radiation environment and with personal **dose controlled**, it is permissible to enter the environment for operation.
Dose rate≤1Sv/h

Unable to enter **high-dose-rate** environments, making it hard to conduct timely disposal.

Background

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In response to the urgent need for emergency response in extreme radiation environments such as nuclear accidents, this study has developed a small and medium-sized robot platform system that can perform surveys, monitoring, and disposal, and has high radiation resistance.

02 Main Research Content

Introduction

Tasks

- **Radiation-Resistant Design**
- Mechanical Design
- Circuit&Control System Design

03 Development for Robot

Development for Robot

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Requirements Analysis

Machanism

Resistant for Electrionic System

Electronics

Minimum System

Radiation-Resistant Robotic System

- Motor
- Driver
- Control
- Commun ication
- Camera
- Power

1） Motor
2） R、L、C、D
3） Transister
4） MosFET
5） DC-DC
6） Crystal
7） Flash
8） Encoder
9） Communication
10） MCU
11） WiFi Module
12） CMOS

Robotic Arm/ End Effectors

Sensor(Camera)

Main Part

Communication

Component - Circuit - System

Analysis and research are conducted in a hierarchical and phased manner.

Resistant Resistance Research

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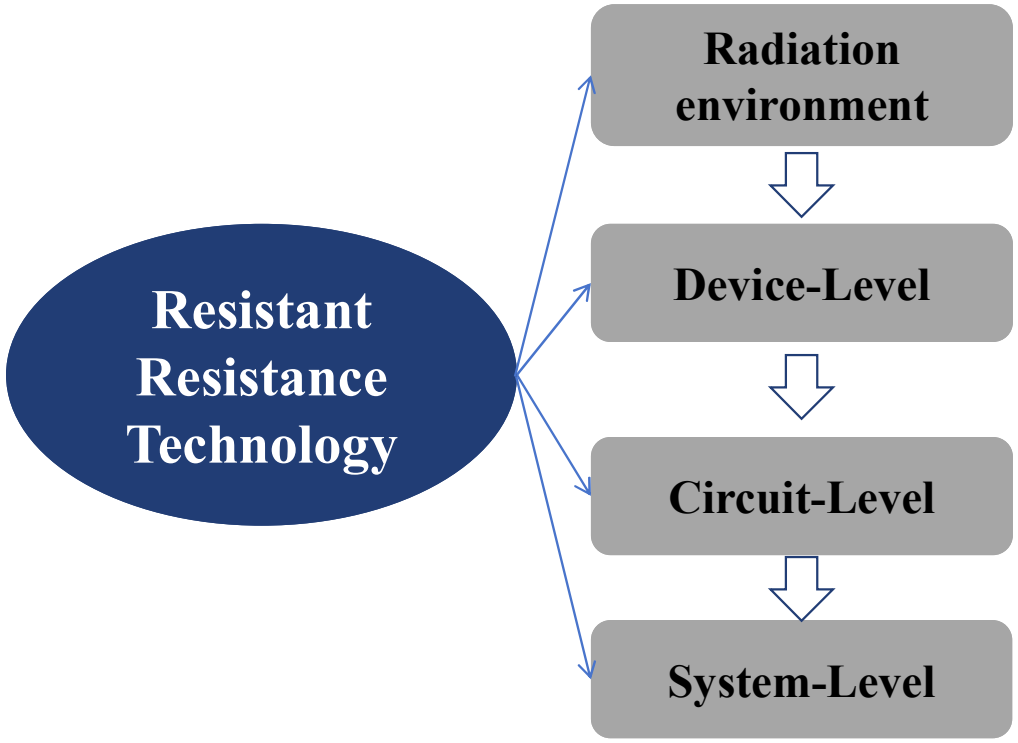
Multi-level, Lightweight Radiation-Resistant Resistance Technical System



Resistant Resistance Research

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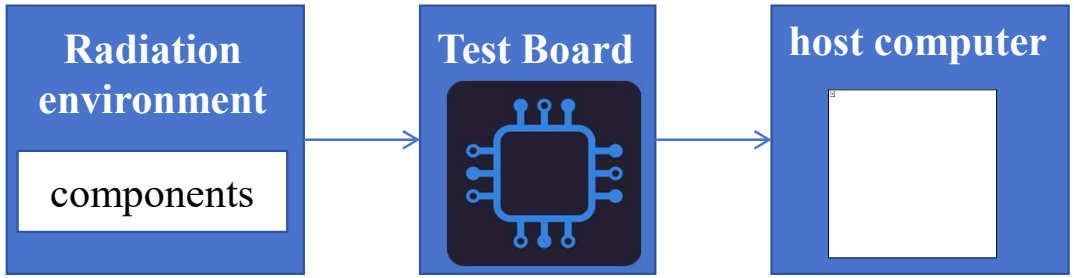
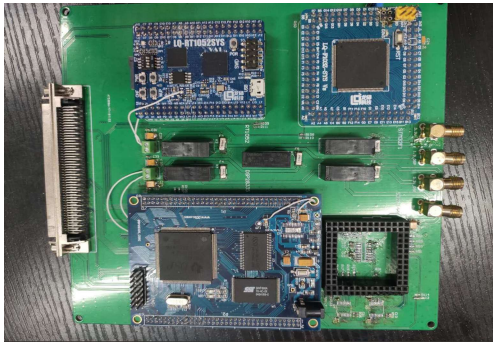
Online Testing Platform for Radiation-Resistant Performance of Electronic Components and Devices



Online Testing Platform Design Block Diagram

- over **200 types** of components
- with a total sample quantity exceeding **20,000 units**
- Build a radiation-resistant database

Testing Platform



Components being tested

Resistant Resistance Research

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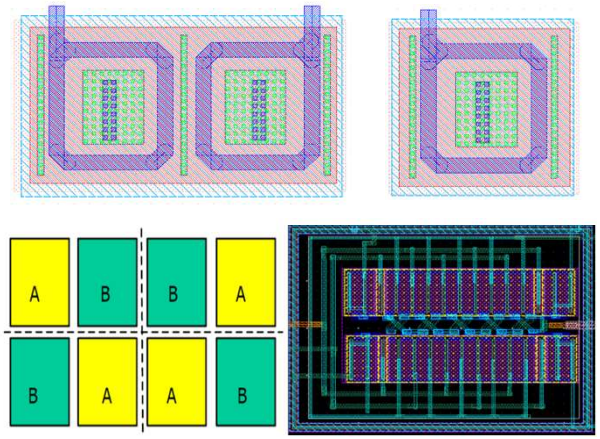
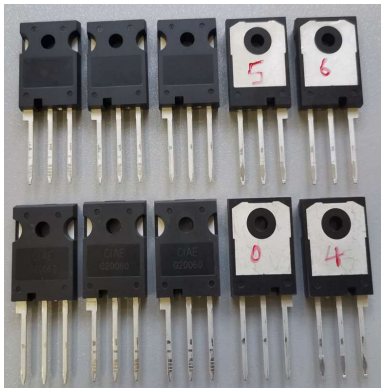
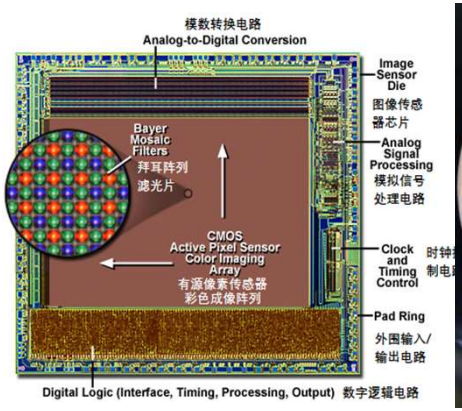


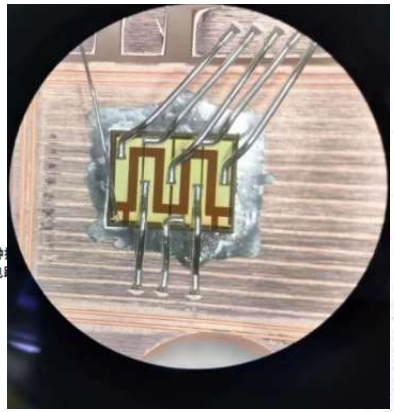
Layout-design

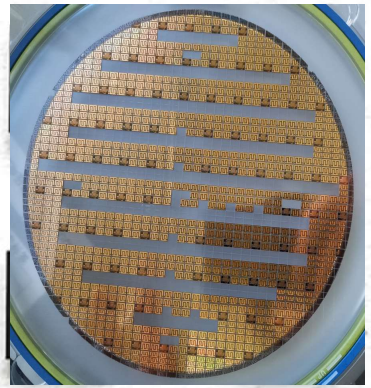
Design tools such as Candence, TCAD

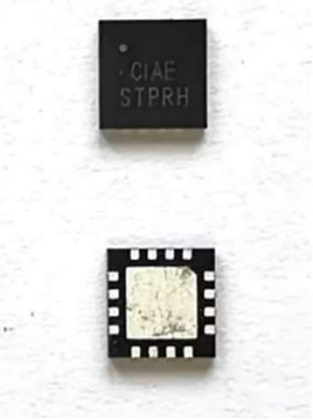
- Radiation-Resistant digital chip - Three-line decoder (Chinese first with 1.17 MGy radiation resistance)
- Radiation-hardened power device - GaN NMosfet (20 KGy)
- Radiation-hardened analog chip - Operational amplifier(18 KGy)











Radiation-Resistant digital chip

Resistant Resistance Research

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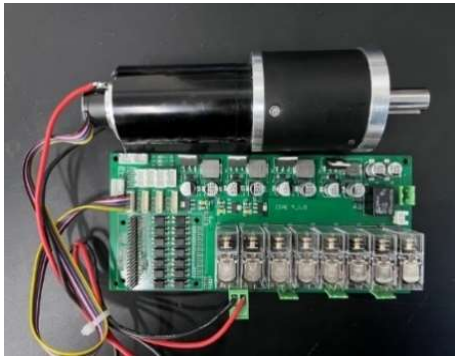
Circuit-level Design

Self-developed circuit modules: **5 types and 8 categories**, including (2 types) radiation-resistant **main control module**, **camera modules**, **electric driver module** (3 types), radiation-tolerant **communication module**, and **high-radiation monitoring module**.

motor driver



main control

camera

Resistant Resistance Research

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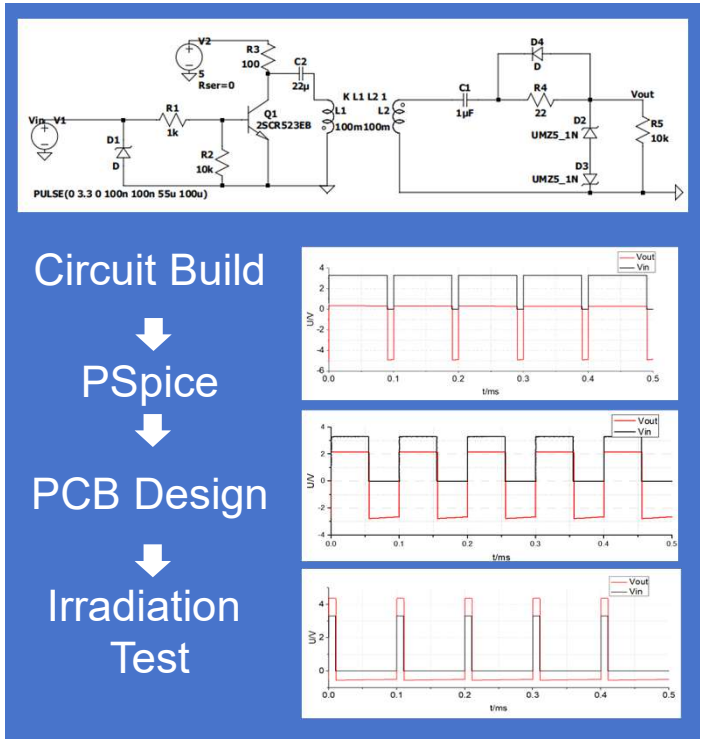
Circuit-level Design

The integrated circuit devices used in traditional H-bridge circuits are difficult to harden,

Therefore , a unique form of radiation-resistant isolated circuit has been designed.

motor driver



<100Gy → **>10000Gy**

Patant Certification

Resistant Resistance Research

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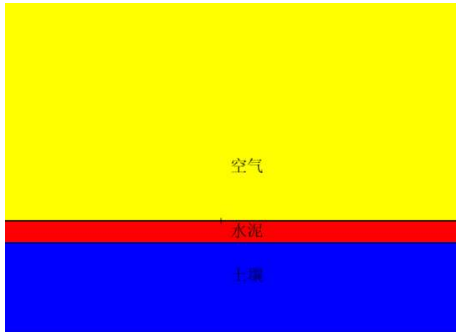
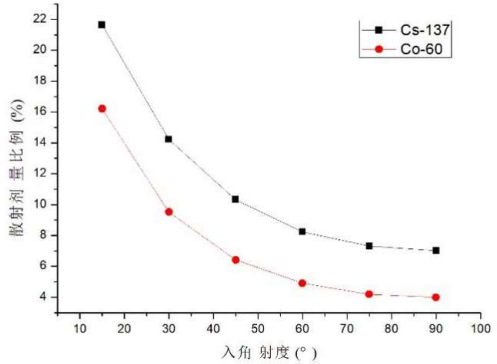
System-level Design

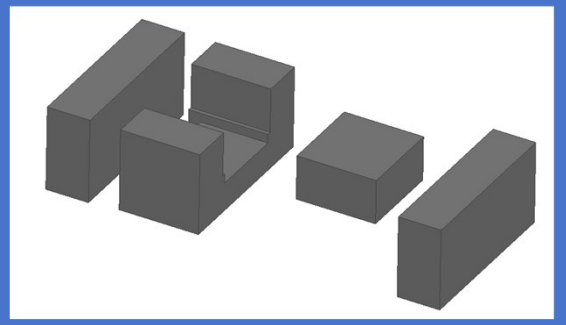
- Targeting main control circuits with weak radiation resistance, hardening measures are implemented.
- Radiation in the site is mainly derived from the space above the ground; therefore, during the shielding design, the design can be optimized to reduce weight.

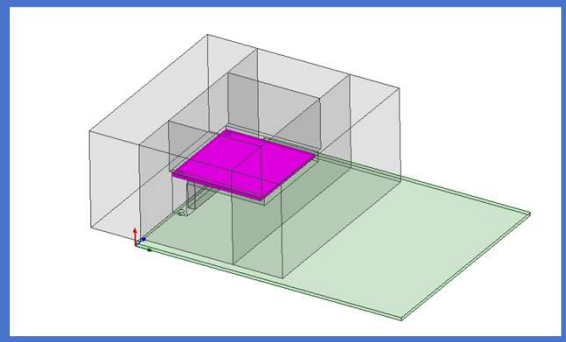


MCNP Simulation



variation of scattered dose proportion with incident angle





Shield for Main Control Circuit

System-level Reliability

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System-level Reliability

Data Validation	Parameter Monitoring	Dose Monitoring
● Verification of Instruction ● Feedback Information	● voltage ● current ● speed ● ……	Cumulative Dose Estimation Circuit

Necessary functions such as distance limit prompt and collision prompt buffer.

To achieve high definition in video surveys of radiation environments, convolutional neural network-based image denoising processing has been implemented simultaneously to further improve image quality.

Without Radiation

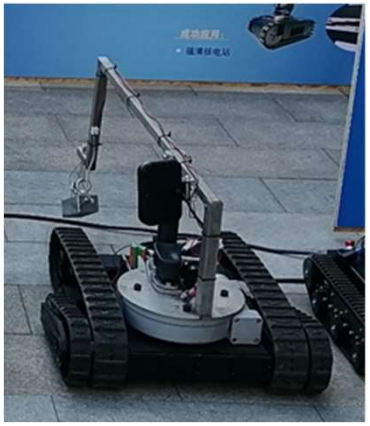
In Radiation Environment

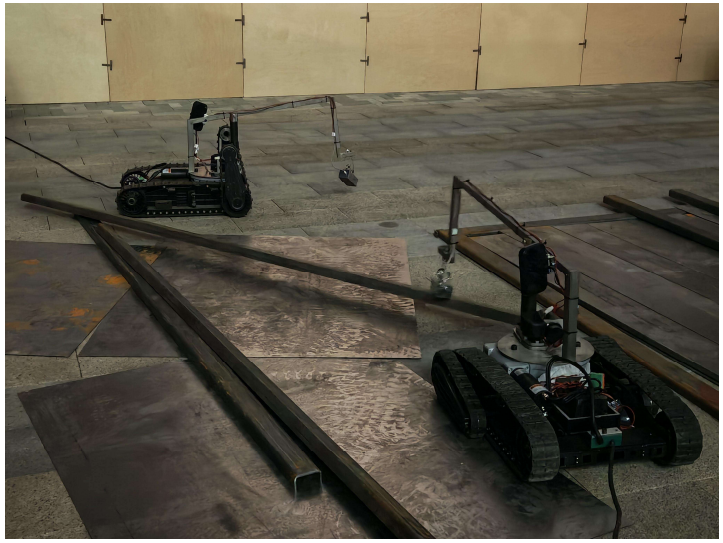
After processing

Radiation Resistant Inspection and Disposal Robot

- Remote-controlled inspection and object-handling operations in high-radiation environments under operator supervision
- Equipped with interchangeable end-effectors to perform video monitoring, object gripping and other diverse tasks.

Total accumulated dose tolerance without shielding	**> 10000 Gy**
Chassis dimensions	**< 680×630×150 mm**
Maximum gradient	**> 30°**
End-effector payload (of robotic arm)	**≥10 kg**





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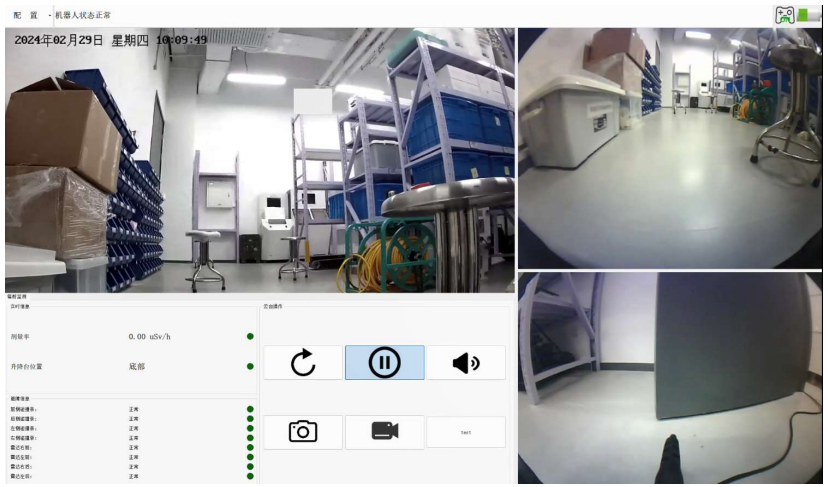
Radiation Resistant Inspection Robot

- Remote-controlled inspection and object-handling operations in high-radiation environments under operator supervision
- Equipped with an High-Definition Camera and High-brightness Lighting Lamp

Total accumulated dose tolerance without shielding	> 10000 Gy
Chassis dimensions	400mm×400mm×350mm
Weight	<35kg
Maximum gradient	> 10°



04 Application Cases

Application Cases

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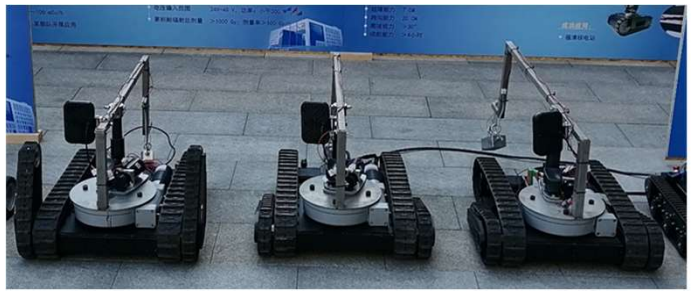
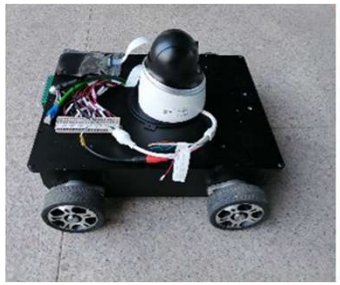
In 2025, 9 collaborative robots were upgrated .With those robots ,we successfully handled a stuck source incident involving 1.7×10^5 Ci. The robots continuously operated for more than 10 hours under a dose rate of 1000-2000 Gy/h, and successfully completed the task.






Intelligent Robotic Technology

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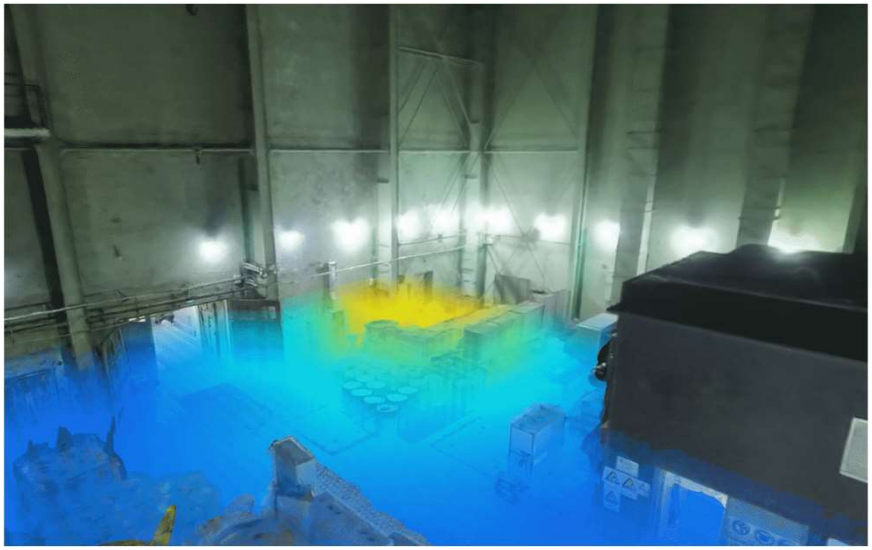
Inspection Robotic Dogs

- Combination of the detection chip, robot and LiDAR
- Remote control scan in nuclear facilities,

  reduce personnel radiation dose



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Thanks!

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