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RESEARCHING NUCLEAR REACTORS DEPLOYED AT SEA FROM A 3S PERSPECTIVE

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ABSTRACT

In 2024, an interdisciplinary research project on marine nuclear reactors was initiated at Uppsala University (UU).

The research focus is on challenges associated with nuclear reactors deployed at sea, weather for nuclear propulsion purposes or electricity generation. This contribution reports on the first results of the project.

PROJECT DESCRIPTION

This project concerns research on nuclear safety, security, and safeguards (3S) for marine nuclear reactors for propulsion or electricity production. There are two goals; to i) identify challenges and solutions related to safeguards and security issues for civilian marine nuclear reactors thereby promoting safeguards and security by design, and ii) to investigate legal and regulatory aspects of such reactors.

The three project phases are:

- **Phase I**: Overview of marine reactor concepts and their deployment. Objective is to assess applicability of current safeguards and security practises and identify research gaps.
- **Phase II**: Case studies of selected concepts. The objective is to characterize the nuclear material, allowing for studies related to its verification and proliferation resistance assessments. Research on the legal frameworks will be initiated.
- **Phase II**: Is expected to deliver recommendations on technical solutions to safeguards and security challenges, ie. the verification of nuclear material and the prevention of unauthorized access to the nuclear material. Non-technical recommendations will concern regulatory pathways for ship-based reactors in Sweden, the EU and internationally.

This contribution reports on findings from Phase I.

FINDINGS FROM PHASE I

PREVIOUS EXPERIENCE

Civilian experience of marine nuclear reactors already exists:

- NS Savannah from the US,
- NS Otto Hahn from Germany,
- NS Mutsu from Japan and
- NS Sevmorput from the Soviet Union, and
- Nine Russian nuclear propelled icebreakers.

In 2018, floating nuclear power plant Akademik Lomonosov (a 35 MWe co-generation plant) went into operation in Russia.

Figure 1. Russian floating nuclear power plant Akademik Lemonosov. Photo from www.fnpp.info.

Military experience exists from the 1954-1977 United States Army Nuclear Power Program (ANPP), focused on small light water reactors (LWRs).

Reviewing civilian and military projects shows that:

- technical information (characteristics, operation and construction) about the reactors can often be found
- limited information is available on associated nuclear infrastructures, maintenance, fuel storage nuclear safety, security and safeguards.

ONGOING RESEARCH EFFORTS

The interest for marine applications includes both LWR concepts and Generation IV (Gen IV) concepts and applications range from nuclear propulsion to electricity generation (e.g. barge ships and floating platforms):

- LWR concepts are claimed to offer advantages related to its mature technology and long operating experience,
- Gen IV concepts are claimed to offer advantages associated to refuelling, size and safety.

FINDINGS FROM PHASE I

Several research projects were initiated recently

- research projects in academia or research institutes
- projects initiated or driven by companies and organisations representing the shipping industry (maritime classification societies, shipping companies, dockyards etc) as well as nuclear reactor developers and vendors.

There are also examples of projects involving both researchers and companies/organisations.

SAFEGUARDS AND SECURITY CONCERNS

Surprisingly little research on safeguards and security by design for marine applications exists.

Some publications pinpoint unique safeguards and security challenges/opportunities associated with floating nuclear power plants and small modular reactors (SMRs). Examples of identified technical proliferation and security includes:

- difficulties to do verification of nuclear material on board, as it is contained in sealed vessels except in dedicated service stations,
- issues related to data transmission,
- physical protection and threat situations including piracy, sabotage, hostage situations and attacks,
- security arrangements around spent fuel and radioactive waste management.

A “manufacture-own-deliver-operate-return” concept has been proposed to reduce concerns, especially related to ownership transfers and developments of new front- and back-end activities. However, many issues remain unresolved.

In addition, many issues relating to regulatory frameworks, licensing and operating criteria remain.

Figure 2. The Seaborg barge ship is one example of a marine application of Gen IV nuclear reactor technology. Photo from Seaborg Technologies.

CONCLUSION AND OUTLOOK

Project focus so-far on gathering information on potential deployment and operation of nuclear reactors on ships, to set the stage for future research on 3S research on marine reactors.

Phase II will be devoted to case studies. These will include technical safeguards and security assessments for selected concepts. Simulations of the fuel irradiation will be performed to enable analysis on nuclear material verification, material attractiveness and physical protection.

Studies related to regulatory frameworks will be initiated, shedding light on rights and responsibilities with respect to safety aspects around the selected concepts.

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