Rethinking the Role of the Human in Advanced Reactors

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RISK PILOT
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Engineering Expertise & Human Understanding

OUR ROLE

Nuclear organizations are facing major investments in modernization, lifetime extensions, new build projects, waste management facilities, infrastructure development, and decommissioning.

Rejlers helps customers develop, verify, and deliver nuclear facility and infrastructure projects through specialist expertise in nuclear safety, engineering, project delivery, and infrastructure development.

Core nuclear capabilities

- Safety & Licensing
- Facilities & systems
- Nuclear infrastructure
- MTO / Human Factors

Rejlers group:

There is an implicit assumption about advanced reactors & SMRs

THE DESIGN ARGUMENT

Smaller, simpler core

Typically, up to 300 MW(e). Fewer mechanical systems; in some designs, primary components integrated inside the pressure vessel.

Passive safety systems

Natural circulation, gravity, convection. Cooling and containment maintained without operator action, in some designs for 72 hours or beyond.

High automation

Most routine plant functions performed automatically, with operators supervising and intervening only in abnormal conditions.

THE ECONOMIC ARGUMENT

Staffing is one of the largest operational expenses of a nuclear plant, & SMRs have to compete on cost.

Fewer people are needed, so plan for fewer people

Both arguments point the same way, and neither of them is unreasonable. But is the conclusion valid?

These designs also broaden what people have to do

Multi-unit and remote operation

One crew responsible for several units that may be in different operating states. In some concepts, a control room that is not co-located with the reactor. The economic case for SMRs strongly favours multi-unit deployment.

New missions and flexible operation

District heating, hydrogen, industrial process heat, desalination. Load-following alongside intermittent renewables rather than steady baseload generation.

New actors and business models

Start-ups and private consortia as vendors. Licensees with no prior nuclear experience, including industrial end users and municipal utilities. Vendor-led maintenance and operational support.

None of these three make the human role smaller. Every one of them adds coordination, communication and situational awareness demands that a single-unit, single-mission, single-organisation plant never had to carry.

More than 80 SMR designs are in development worldwide, and no design has all of these characteristics.
How far a given plant departs from conventional operation depends on the design and the operational concept chosen.

This challenge is not unique to nuclear

Highly automated, remotely supervised, multi-unit operation has already been deployed elsewhere. Those industries found that it changes what the human is doing rather than removing the human, and that the new role has its own demands and its own failure modes.

Oil & gas	Norway spent two decades moving platforms towards remotely operated facilities controlled from onshore centres, and mapped out where the limits are: situational awareness, command and control responsibilities, and diagnosing problems with nobody physically present. Remote operation is achievable, provided the operational concept is defined in detail before the technology is locked in.
Maritime	Operators supervising autonomous vessels could reasonably manage one or two. Simultaneous events across several ships rapidly exceeded safe workload limits.
Aviation	Remote towers are operational in Sweden and Norway. Managing more than one airport simultaneously introduced spatial disorientation, alarm overload and unsafe workload.
Offshore wind	Central control rooms supervise dozens of farms; some substations are visited once a year. How many assets one crew can safely supervise depends less on the level of automation than on information architecture and organisational design.

A repeating pattern: automation redistributes the human contribution to risk. It does not remove it.

Sustained vigilance, detecting subtle deviations, and standing ready to act in rare and unfamiliar fault conditions.

These may be precisely the tasks that humans are worst at performing reliably.

Roth et al., cited in Blackett et al. (2026), HFE Principles for SMRs – Interim Report 1.

Automation offered as a way of reducing human error risk can, under certain conditions, create a different and harder-to-detect category of failure: the failure to notice, the failure to understand, and the failure to act in time when automation behaves unexpectedly.

The human role in an advanced reactor is a capability we design in. It must be specified, resourced and supported like any other part of the safety case.

Humans offer sensemaking, early detection of degraded conditions, and adaptive response to the unexpected. These are the capabilities that keep a complex system working when its design assumptions run out. They have to be designed in, resourced and supported from the beginning, or they will not exist later when the plant is built and operated.

Instead of asking

“How few people can we run this with?”

We should be asking

“What do we need people to be able to do here, and how do we make sure they can do it?”

Humans are a critical enabler of resilience, safety and performance

Three outcomes that an advanced reactor cannot obtain through technical engineering alone.

Resilience

Every safety case has a boundary. Beyond it, what remains is the capacity of people to make sense of an unfamiliar situation and act well in it. That capacity is there when the role, the interfaces and the training were designed to support it.

Safety

Passive and automated systems deliver their safety function only if they are in a reliable condition when called upon. That condition is produced by people maintaining, inspecting, testing and configuring them. Designing that work well is what makes the safety case true in operation.

Performance

Load-following, cogeneration and multi-unit operation all depend on crews reconfiguring the plant quickly and confidently. Good human-system design shows up in availability and in avoided trips, not only in safety metrics.

The advantages of designing for people

A licensing case you can evidence – regulators increasingly require novel operating concepts to be justified with evidence that they are safe and workable.

Staffing you can defend – a number you can trace back to what the crew has to be able to do.

Rework you can avoid – decisions embedded in a design are expensive to undo, and human factors work has most influence while the operational concept is still open.

These are commercial arguments as much as safety arguments.

The time to act is now

Staffing levels, automation philosophy, allocation of function and the operational concept are settled at conceptual and basic design. That is the point at which human factors input can still shape the outcome.

1 **Vendors**

Bring human factors in alongside the other engineering disciplines at concept stage, while the operational concept is still open.

2 **Licensees**

Build the in-house competence to evaluate what you are being offered. Intelligent customer capability takes time to grow.

3 **Regulators**

Engage early, before designs are locked in and before licensing submissions are prepared, while there is still time to act.

At Risk Pilot, we are actively working on these challenges

None of these gaps can be closed by a single project or organisation. They need collaboration across researchers, vendors, licensees and regulators, beginning now, in parallel with the design and licensing work already underway.

PUBLISHED

March 2026

HRA taxonomy for SMRs Part 1

SSM 2026:06. Mapping the SMR landscape, from literature review and expert interviews.

May 2026

White paper

"What We Know About SMRs So Far." Five years of research, drawn together.

TODAY

Late 2026

HRA taxonomy for SMRs Part 2

The completed taxonomy and recommendations, built on workshops from Part 1.

Funded by SSM

Late 2026 / early 2027

Organisational factors for SMRs

The first international consensus document on this topic.

A report by OECD NEA WG HOF

Late 2027

HFE principles for SMRs

Case study work on specific designs, testing the analytical frameworks.

Funded by SSM

White paper available on ResearchGate

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