Carnegie Mellon University

Using PRA Insights to Inform Public-Facing Nuclear Safety Communication:

Implications for Singapore's SMR Deployment Considerations

Heshuo June Lin[a], Tatsuya Sakurahara[b]

[a] Department of Engineering and Public Policy, College of Engineering, Carnegie Mellon University, Pittsburgh, PA, USA, junelin060@gmail.com

[b] Risk Analysis and Reliability Engineering (RARE) Laboratory, Department of Mechanical Engineering and Materials Science, Swanson School of Engineering, University of Pittsburgh, Pittsburgh, PA, USA, tsakurahara@pitt.edu

PROBLEM SPACE & OVERVIEW

Motivation: Expanding the Role of PRA in Public Risk Communication

Current role of PRA

- **Evaluates accident scenarios, likelihoods, and consequences**
- **Produces risk metrics such as CDF and LERF**
- **Supports plant operations, maintenance, and regulatory decision-making**
- **Primary audience are regulators, plant operators, and technical specialists**

Source: Nuclear Regulatory Commission

PROBLEM SPACE & OVERVIEW

Research Questions

- **Could risk information generated by PRA also be used to inform public-facing communication about nuclear safety?**
- **How can suitable PRA outputs be selected for translation into public-facing communication?**

This paper proposes selection criteria for identifying PRA outputs suitable for public-facing communication, alongside a possible implementation pathway for newcomer states

THEORETICAL BASIS

Theoretical Basis for Evaluating Public Risk Communication

1 Fischhoff's six concerns on Public risk perception

1. **Familiarity** with the hazard
2. **Comprehension** of its mechanism
3. **Equity** in the distribution of exposure
4. **Dread** that it evokes
5. Audience's sense of **control** over it
6. **Trust** in the institutions managing it

→ Lay audiences do not respond to nominally equal probabilities the same way

2 Fischhoff's developmental stages of risk communication

1. All we have to do is get the numbers right
2. All we have to do is tell them the numbers
3. All we have to do is explain what we mean by the numbers
4. All we have to do is show them they've accepted similar risks in the past
5. All we have to do is show them that it's a good deal for them
6. All we have to do is treat them nicely
7. All we have to do is make them partners
8. All of the above

Warren & Duckett brought engagement (Stage 7) near the front, shifting from communicating risk to the public to communicating with them

Source: Fischhoff (1995, 2015), Warren & Ducket (2026)

CURRENT PRACTICE

Current NRC Approaches to Public Communication Using PRA

1 Reactor Oversight Process (ROP)

01

- **Risk-informed inspection**
- **Four-color significance scheme (green/ white/ yellow/ red)**
- **Public brochure NUREG/BR-0508**
- **Annual public meetings**

- **Colors anchored to ΔCDF/ ΔLERF thresholds, but the brochure defines significance by color position, not the underlying numbers**

- **Sits mainly in developmental stages 1 - 3, emphasizing stage 3**

Source: NUREG/BR-0508, NUREG/BR-0359, NUREG-1935

CURRENT PRACTICE

Current NRC Approaches to Public Communication Using PRA

2 **State-of-the-Art Reactor Consequence Analyses (SOARCA)**

- **Updated source-term/ consequence estimates over NUREG-1150**
- **Booklet NUREG/BR-0359 with three plain-language findings on the landing page**
- **Translation techniques: scientific notation explained as "1 in X" odds**
- **Covers stages 1 - 4**

No systematic framework currently exists to guide the selection of PRA information for public-facing translation

SOARCA preliminary findings on the NRC website

"The analyzed accidents would cause essentially zero immediate deaths and only a very, very small increase in the risk of long-term cancer deaths."

Source: NUREG/BR-0508, NUREG/BR-0359, NUREG-1935

TWO DIMENSIONS OF ANALYSIS

Proposed Framework for Evaluating PRA Outputs

Dimension 1

Public reception

Fischhoff (2015)
1. Familiarity
2. Understanding
3. Equity
4. Dread
5. Control
6. Trust

Dimension 2

Scientific uncertainty

Schuster & Scheu (2026)
1. Epistemic
2. Methodological
3. Consensus

Shortlisted PRA outputs

Source	PRA-informed output
Typical PRA outputs	Core damage frequency (CDF)
Typical PRA outputs	Large early release frequency (LERF)
ROP	ROP four-color significance scheme
SOARCA	SOARCA qualitative findings

- The first dimension considers how the public receives information
- The second dimension considers the uncertainty embedded within that information

Source: Fischhoff (2015), Schuster & Scheu (2026)

FINDINGS (1 of 2): PUBLIC RECEPTION

Evaluation of the Translatability of PRA-informed Outputs against Fischhoff's Six Public Concerns

PRA output	Familiarity	Understanding	Equity	Dread	Control	Trust
Core damage frequency (CDF)	Low	Low	Not directly engaged	High	Low	Medium
Large early release frequency (LERF)	Low	Low	Low	High	Low	Medium
Four-color significance scheme (as presented in ROP)	Low	Medium	Low	Low	Low	High
Qualitative consequence findings (as presented in SOARCA)	Low	High	Medium	Medium	Low	Medium

Legend

High: PRA-informed output directly engages that concern for a lay audience.

Low: The output engages the concern only weakly or indirectly, such that it would be unlikely to be recognized without additional explanation.

Medium: intermediate level of engagement, where the concern is partially engaged but requires some additional interpretation or supporting context to be communicated clearly.

Not directly engaged: The output contains no information relevant to that concern.

* The rating of each entry has been determined based on the authors' expert judgment

FINDINGS (1 of 2): PUBLIC RECEPTION

Key Insights from Findings 1

1 Understanding

Quantification without explanation

Readers rarely understand 10^{-5} from 10^{-7} without domain knowledge

ROP's color scheme and SOARCA's plain language outputs are broadly understood

2 Equity

Who bears the consequences

LERF does not evaluate the distribution of offsite consequences

ROP colors describe plant performance rather than population exposure

Qualitative findings in the SOARCA mention public health consequences, though without distributional detail

3 Trust

Institutional trust shapes how PRA outputs are interpreted

A green finding is only reassuring when the issuing institution is trusted

Translation requires particular attention to understanding, equity, and trust

FINDINGS (2 of 2): UNCERTAINTY

Findings: Scientific Uncertainty Across PRA Outputs

Epistemic uncertainty: Known or unknown research gaps
Methodological uncertainty: Limitations in data collection, modeling, or analysis
Consensus uncertainty: Inconsistent or contradictory findings or expert interpretations

PRA output	Epistemic uncertainty	Methodological uncertainty	Consensus uncertainty
CDF	Low to Medium	Low to Medium	Low
LERF	Low to Medium	Medium	Low
Four-color scheme (ROP)	Low	Medium	Low
Qualitative consequence findings (SOARCA)	Medium	High	Medium

Legend
Low: The impact of each uncertainty type is comparatively limited or well characterized

Medium: Has a noticeable influence on the output

High It plays a substantial role and should be explicitly considered when translating the output for lay audiences

* The rating of each entry has been determined based on the authors' expert judgment

FINDINGS (2 of 2): UNCERTAINTY

Observations Between Translatability and Uncertainty Disclosure

1 Observation 1

Typical PRA outputs

CDF and LERF have relatively low uncertainty, supported by mature component failure databases, well-established modeling assumptions, and broad PRA consensus

Lower uncertainty,
Harder to understand

2 Observation 2

Qualitative consequence findings

SOARCA's plain language reads as definitive (eg "zero immediate deaths") though source-term, evacuation, and emergency-response assumptions carry substantial uncertainty.

Easier to understand,
Might suppress uncertainty

3 Observation 3

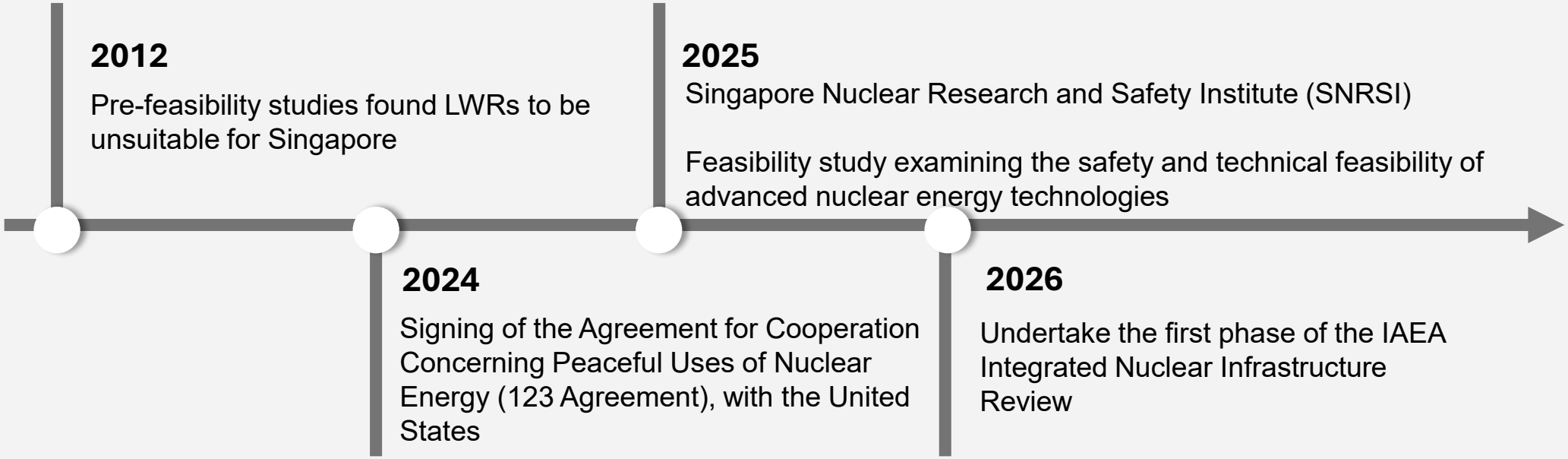
Translation should improve understanding without concealing uncertainty

Qualitative findings translate the underlying analyses into plain language, resulting in the uncertainty from those findings being less apparent

Improving comprehension should not come at the cost of suppressing uncertainty

SINGAPORE CONTEXT

Singapore's Nuclear Energy Context



Source: International Atomic Energy Agency (IAEA) , Ministry of Trade and Industry (MTI), Energy Market Authority (EMA)

INSIGHTS GLEANED

Applying the Framework to Singapore

1. **CDF and LERF alone may not sufficiently address equity concerns in dense urban settings**

2. **Four-color schemes rely on institutional trust**

3. **Qualitative findings improve understanding but make uncertainty less explicit**

<u>One possible implementation pathway - A nuclear safety guidebook</u>

- Plain-language explanations of key PRA outputs
- Structural constraints of dense urban geography
- The institutional architecture being established
- Mechanisms for ongoing public engagement

Source: International Atomic Energy Agency (IAEA) , Ministry of Trade and Industry (MTI), Energy Market Authority (EMA)

CONCLUSION AND FUTURE WORK

Conclusion

1. **A two-dimension selection criterion:** Public communication and scientific uncertainty
2. **Continued exploration:** A work in progress built on prior work. This framework is intended as an initial step and requires further validation
3. **Singapore as an implementation example,** where dense geography and greenfield regulation sharpen the question

Effective public risk communication requires the expertise of *subject-matter specialists, risk & decision analysts, behavioral scientists, and system specialists (Fischhoff)*

This work aims to plant a seed for a new research pathway in the PSAM community: strengthening the use of PRA-derived outputs for risk communication with lay audiences

Thank You

Heshuo June Lin, Tatsuya Sakurahara
junelin060@gmail.com, tsakurahara@pitt.edu

Full paper: https://www.iapsam.org/PSAM18/papers/JU324-PSAM18.pdf