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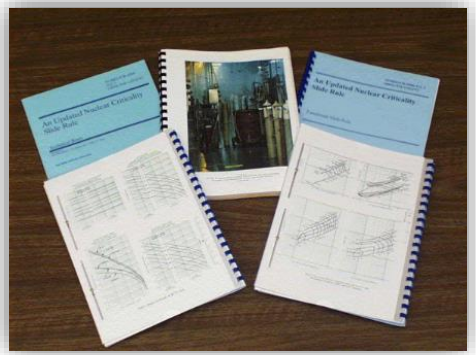
IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

STATUS OF THE SLIDE RULE UPDATE

2024 Annual NCSP Technical Program Review

Speaker: Aurélie BARDELAY
PoC: Johann HERTH

SLIDE-RULE



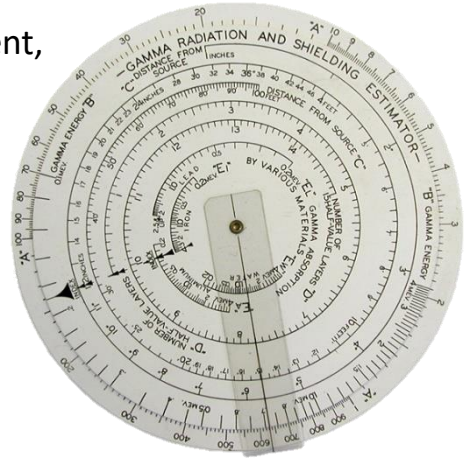
[HISTORY AND PURPOSE

An Updated Nuclear Criticality Slide Rule dated of April 1997

- ORNL/TM-13322/V1 & V2: Technical Basis / Functional Slide Rule

The document gives an order of magnitude estimates of key parameters, useful for emergency response staff and public authorities for U systems only:

- The magnitude of the **number of fissions** based on personnel or field radiation measurements or various critical system parameter inputs,
- Prompt Neutron- and gamma- **dose** at variable unshielded distances from the accident,
- The **skyshine** component of the dose,
- Time-integrated radiation **dose** estimates,
- One-minute **decay-gamma** radiation dose,
- **Dose-reduction factors** for variable thicknesses of steel, concrete and water.



SLIDE-RULE

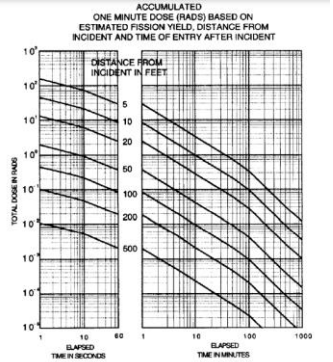
[LONG TERM DOE/NNSA NCSP – IRSN COLLABORATION

- **NCSP wants to develop and maintain modern Slide Rule**

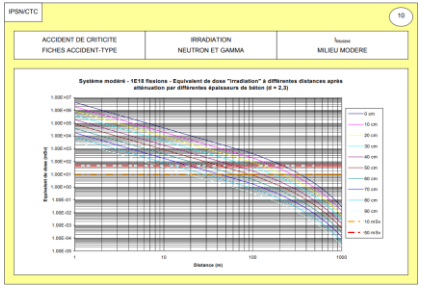
Accident analysis:		Budget Priority Technical Priority
Field-deployable emergency response methods on portable, handheld platform	Develop and maintain modern, accident analysis capability (SlideRule)	

- **IRSN wants to review and improve its French "Slide Rule"**

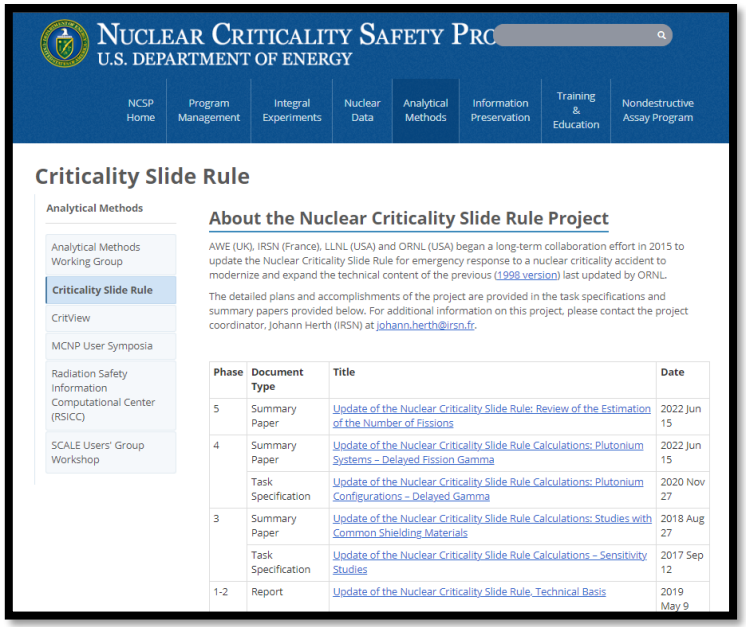
- **Proposal of a complete work, divided into several phases**



US Slide-Rule



IRSN abacus



https://ncsp.llnl.gov/analytical-methods/criticality-slide-rule

[PHASES (BRIEF RECAP)

1

[INITIAL CONFIGURATIONS – [U SYSTEMS]

- **Objectives:** Redo with modern radiation transport tools, for the same configurations and assumptions, the calculations performed initially for the 1997 estimation of the doses for 5 uranium systems.

- Evaluation of N/P prompt doses and delayed gamma dose rates over time.

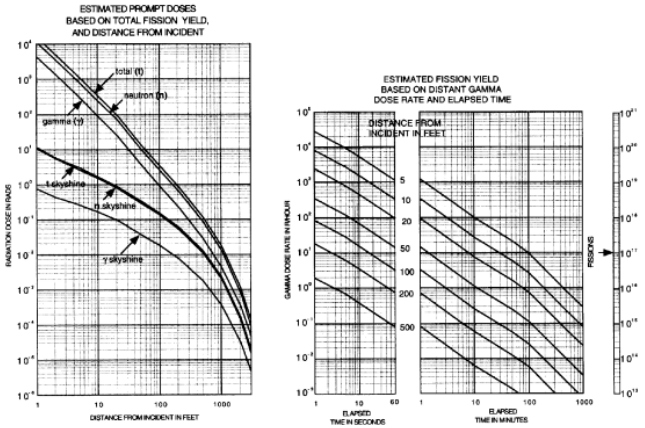


Figure 13 Damp $U(93.2)_3O_8$ @ $H/^{235}U = 10$

[PHASES (BRIEF RECAP)

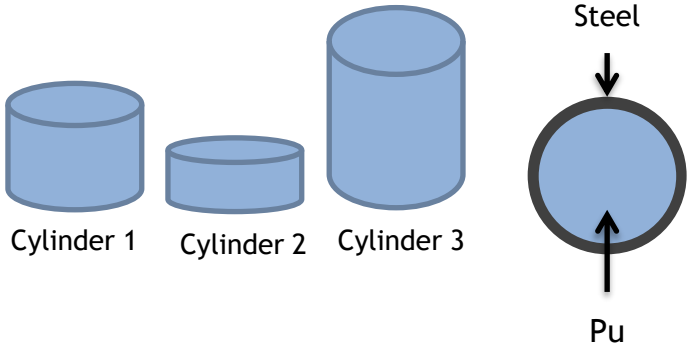
1

2

[NEW CONFIGURATIONS - [PU SYSTEMS]

Introduce Pu systems (bare sphere)
- Prompt N/P dose
- ^{239}Pu metal homogeneously mixed with water
  5 moderation ratios (H/Pu = 0, 10, 100, 900 and 2,000)

Additional configurations
- New source geometries (bare cylinders)
- Steel reflected sphere



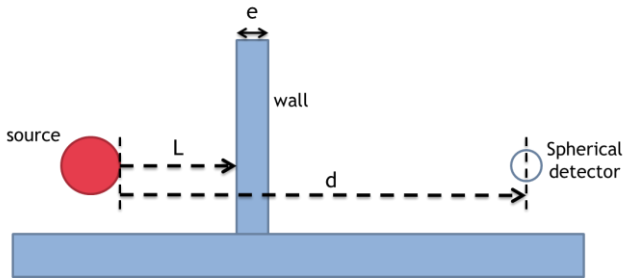
[PHASES (BRIEF RECAP)

1
2
3

[SENSITIVITY STUDIES – [U SYSTEMS]

Objectives: quantify the impact of various shielding materials / thicknesses and sensitivity studies on radiation doses

- **Radiological screen** (lead, steel , concrete, water)
- **Sensitivities studies** (air humidity, ground composition and thickness, skyshine effect)



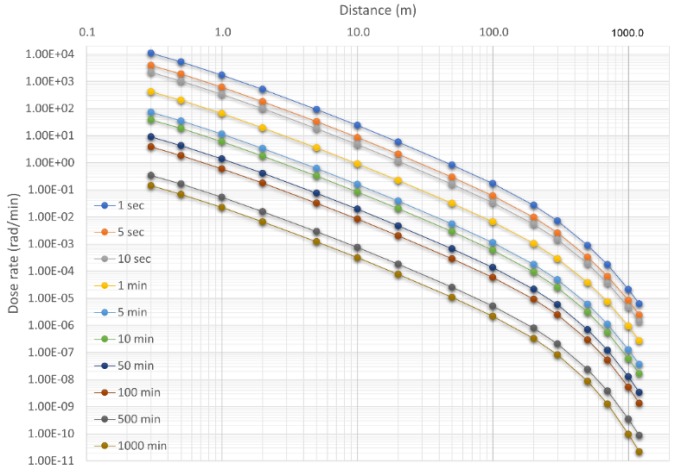
[PHASES (BRIEF RECAP)

1
2
3
4

[DELAYED FISSION GAMMA – [PU SYSTEMS]

Objectives:

- Estimate the fission product release dose rates (created by the accident)



PHASES (BRIEF RECAP)

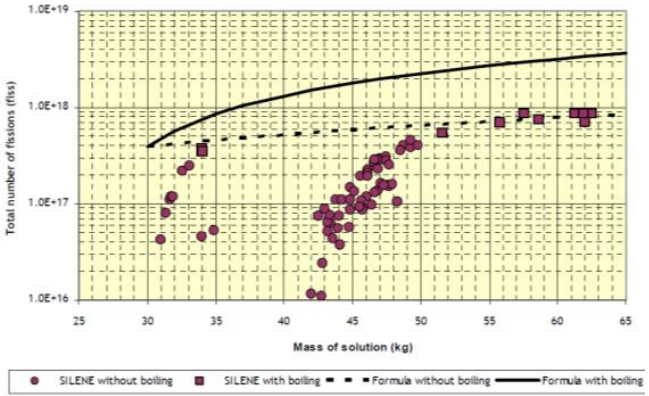
1
2
3
4
5

ESTIMATION OF THE NUMBER OF FISSIONS

Objectives:

- Estimate the total number of fissions for the entire criticality accident duration (including boiling for system with water)

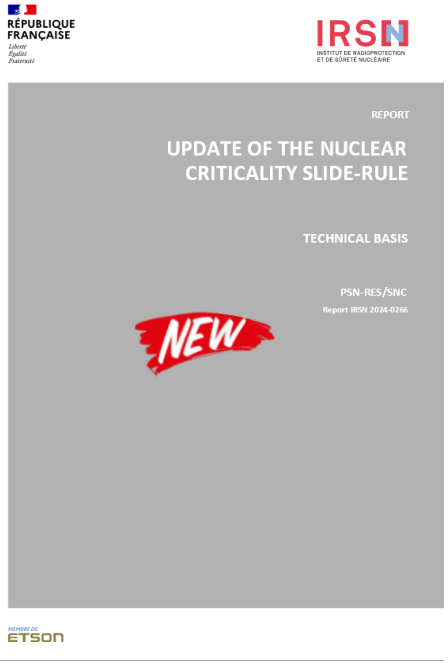
Formulae based on the “heat energy formula”



SLIDE RULE: WORK IN PROGRESS

[REPORT

- Update of IRSN report (**rev. B**) to integrate phase [1-5] with consolidated results
- Imminent release !



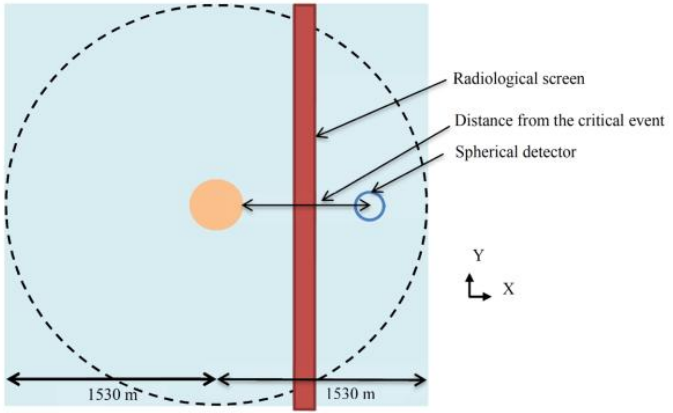
SLIDE RULE: WORK IN PROGRESS

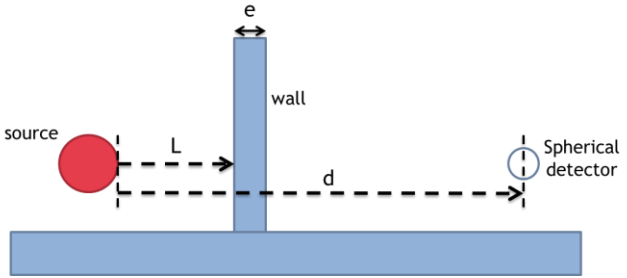
[PHASE 6 – PU SYSTEMS

Key focus:
- Quantify the impact of various shielding materials / thicknesses and sensitivity studies on radiation doses, replicating the calculations done for uranium systems.

Shielded configurations:
- Radiological screen (lead, steel , concrete, water)
- Thickness of the wall (e)
- Position from the source and the detector (L, d)

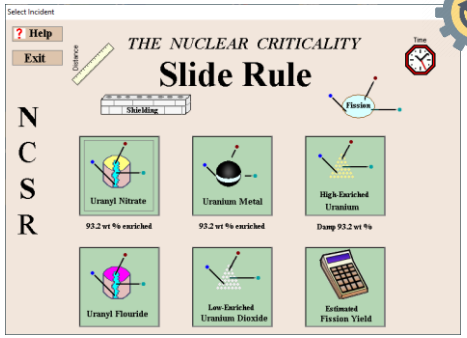
Sensitivities studies:
- Air humidity
- Ground composition and thickness
- Skyshine effect





Results expected early 2025

SLIDE RULE: WORK IN PROGRESS



[WEB APP

Objectives

- Create a user-friendly emergency response application for handheld devices (e.g., smartphone or tablet PC)
- Replace the existing tool with the up-to-date results

Data visualization platform

- Based on Streamlit (open-source Python framework)
- Reactive interface (auto-adapts to data changes and different devices)
- Code and datasets hosted on IRSN's GitLab (open to external companies)

Explore results database

- For all users
  - Visualize multiple series of results
  - Compare results
- For NCSP analytical team
  - Find anomalies (missing values, high uncertainty, discrepancies)

Calculate the number of fissions and adjust the associated dose

https://sliderule.streamlit.app/

https://gitlab.extra.irsn.fr/snc/SlideRule

SLIDE RULE: WORK IN PROGRESS

[WEB APP

Already available in the app

- Prompt doses results for U bare systems
- Radiological screens for U systems
- Number of fissions calculation (based on formulae)
- Interpolation for any distance

Under development

- Aggregate all results from the updated report (Pu results, delayed gamma doses, sensitivity studies)
- Interpolation for custom shield thickness values (prompt dose reduction factors)
- Work to conclude on final reference values
- Turn web app into an offline executable

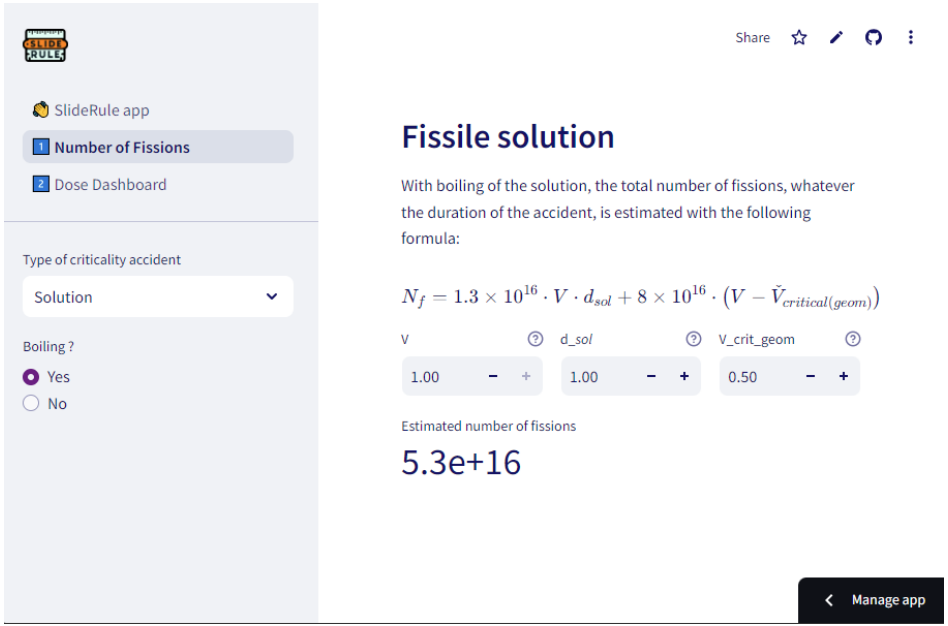
User feedbacks

- List of contact users provided by Doug Bowen → creation of a user group
- To be launch: survey of users' current use of slides rules and future needs
- Submit an idea, request a feature or report a bug → GitLab or contact PoC)

SLIDE RULE: WORK IN PROGRESS

[WEB APP DEMO !

- **Calculate the number of fissions**

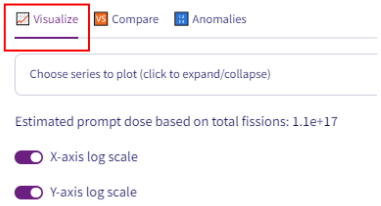


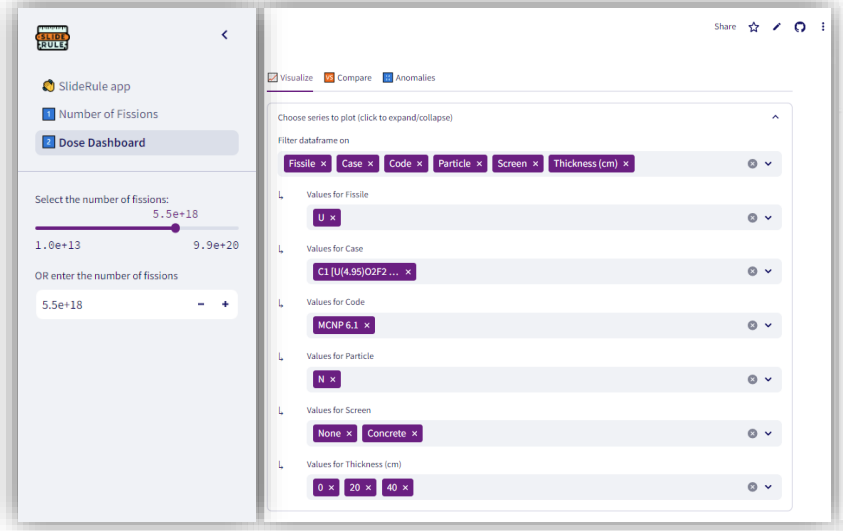
SLIDE RULE: WORK IN PROGRESS

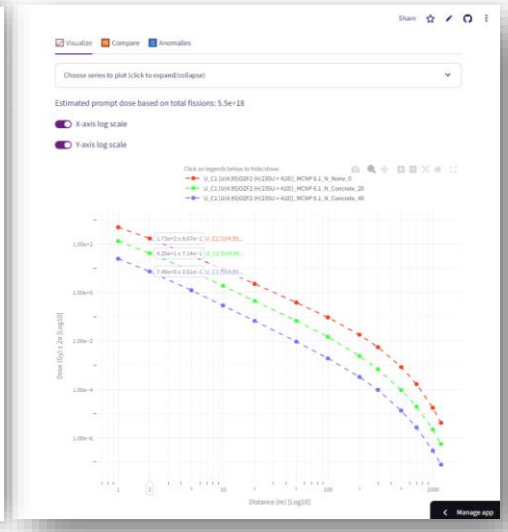
[WEB APP DEMO !

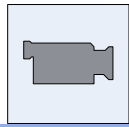
Visualize:

- Select and visualize multiple series at a glance
- Adjust the number of fissions ↔ associated dose





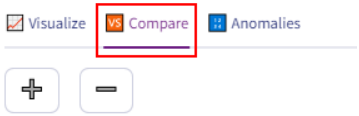


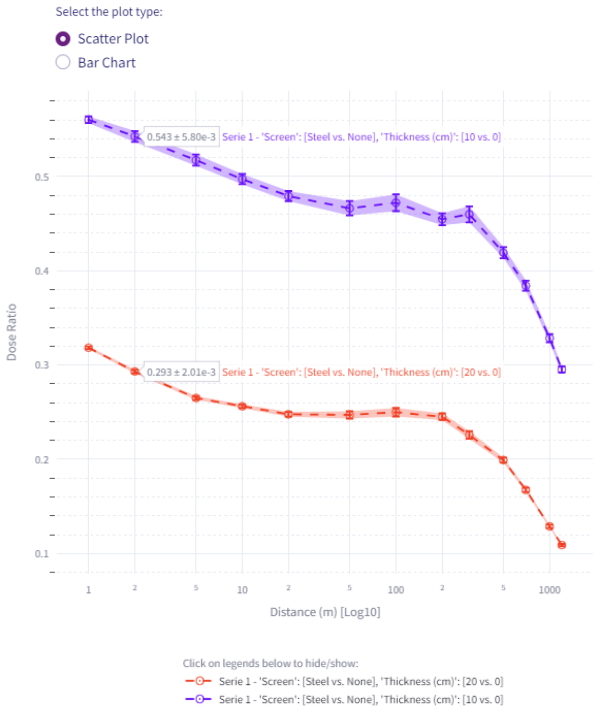


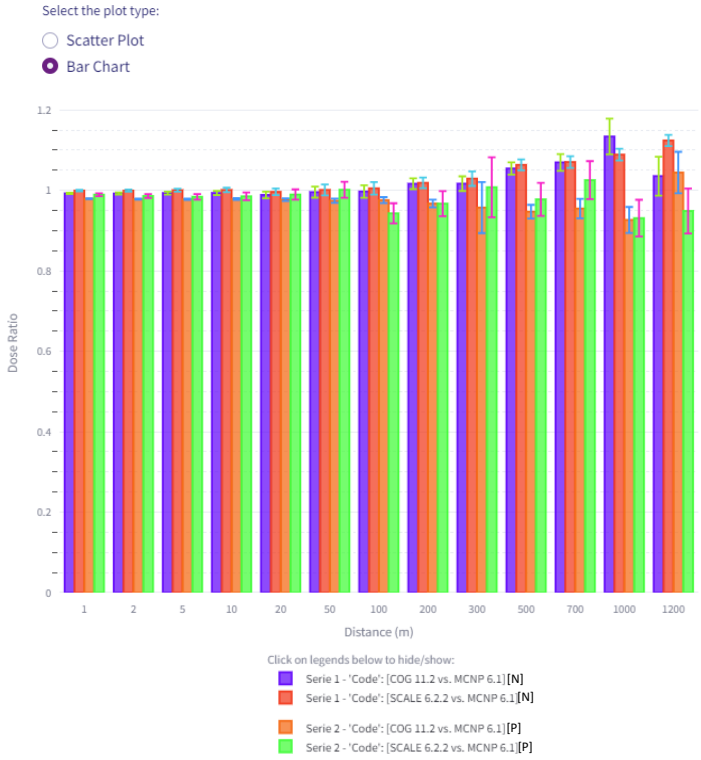
SLIDE RULE: WORK IN PROGRESS

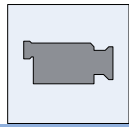
[WEB APP DEMO !

Compare







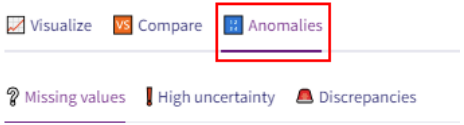


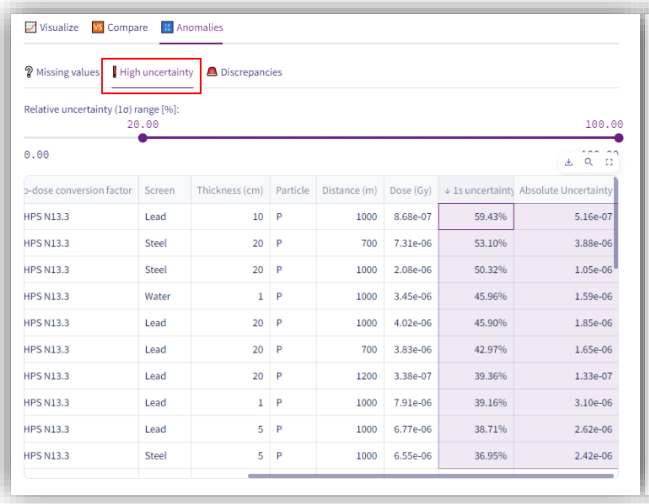
SLIDE RULE: WORK IN PROGRESS

[WEB APP DEMO !

Find anomalies:

- Missing values
- High calculation uncertainties
- Discrepancies between codes





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THANK YOU!

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ET DE SÛRETÉ NUCLÉAIRE

BACK-UP SLIDES

SLIDE-RULE: PHASE 6

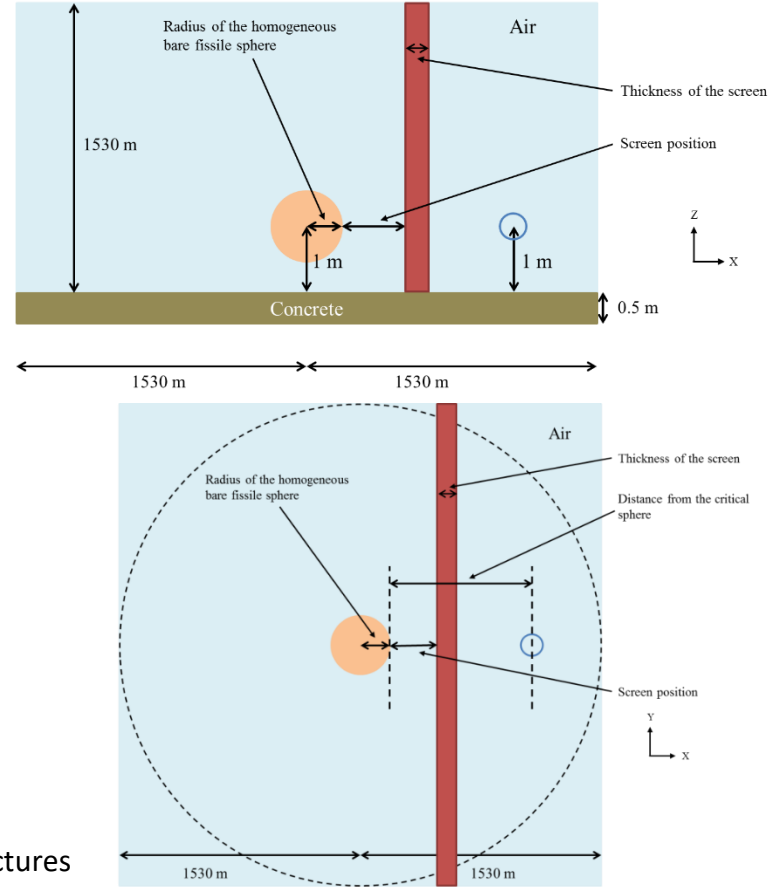
[SHIELDED CONFIGURATIONS

Geometry: one air sky layer (1530m) above 50 cm concrete layer (ground)

Source:
- Pu critical bare spheres – 1 meter over the ground
- 5 moderation ratios (H/Pu = 0, 10, 100, 900, 2.000)
- fission burst yielding a total of 10^{17} fissions

Radiological screens:
- placed halfway between the source and the detector
- 4 compositions : steel, water, lead, concrete
- 5 thicknesses : 1, 5, 20, 40 cm

Dose detection:
- Neutron and gamma prompt doses
- 30 cm to 1.2 km between source and dose detection
- 2 flux-to-dose conversion factors (ANSI/HPS N13.3-2013, fine group structures for neutron and gamma)



SLIDE-RULE: PHASE 6

[RADIOLOGICAL SCREEN POSITION

Objective: evaluate the impact of the screen's position on radiation protection effectiveness

Screen position: (“L”) 6 different positions relative to the total distance "D" (distance between the source edge and the center of the detector): L = 1/4, 1/3, 1/2, 2/3, 3/4, and 4/5 of “D“

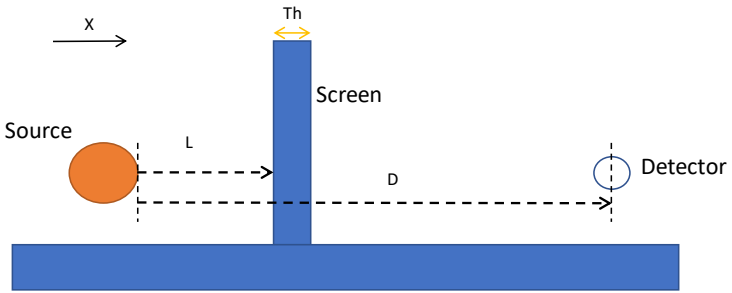
Configurations: cases 1 (H/Pu = 0) and 4 (H/Pu = 900)

Screen

- **Composition**: concrete, water
- **Thickness:** 20 cm

Measurement distances: 1, 2, 5, 10, 50, 100 m

N/P prompt doses



SLIDE-RULE: PHASE 6

[SENSITIVITY STUDIES

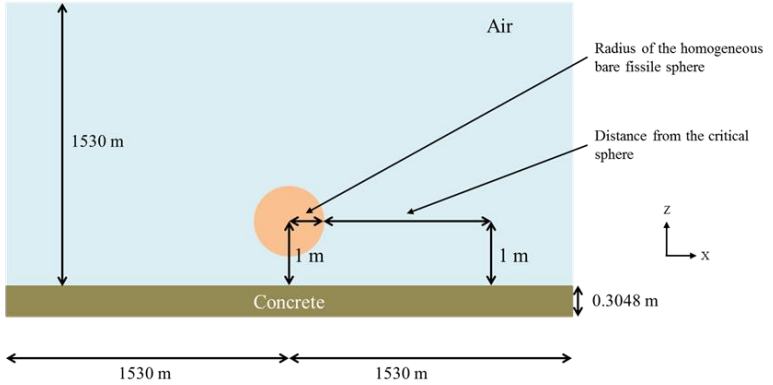
- **Unshielded configurations** (no radiological screen)

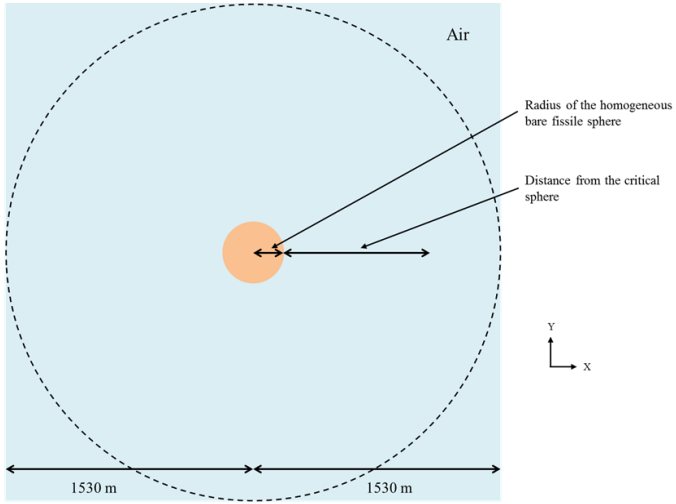
- **Comparison:**
  - **Air composition**: at 10% and 100% humidity
  - **Soil composition:** regulatory concrete and dry soil (without hydrogen).
  - **"Skyshine":** results with a height of 10 m to the the initial height of 1530 m

- **Configurations:** cases 1 (H/Pu = 0) and 4 (H/Pu = 900)

- **Measurement Distances**: all

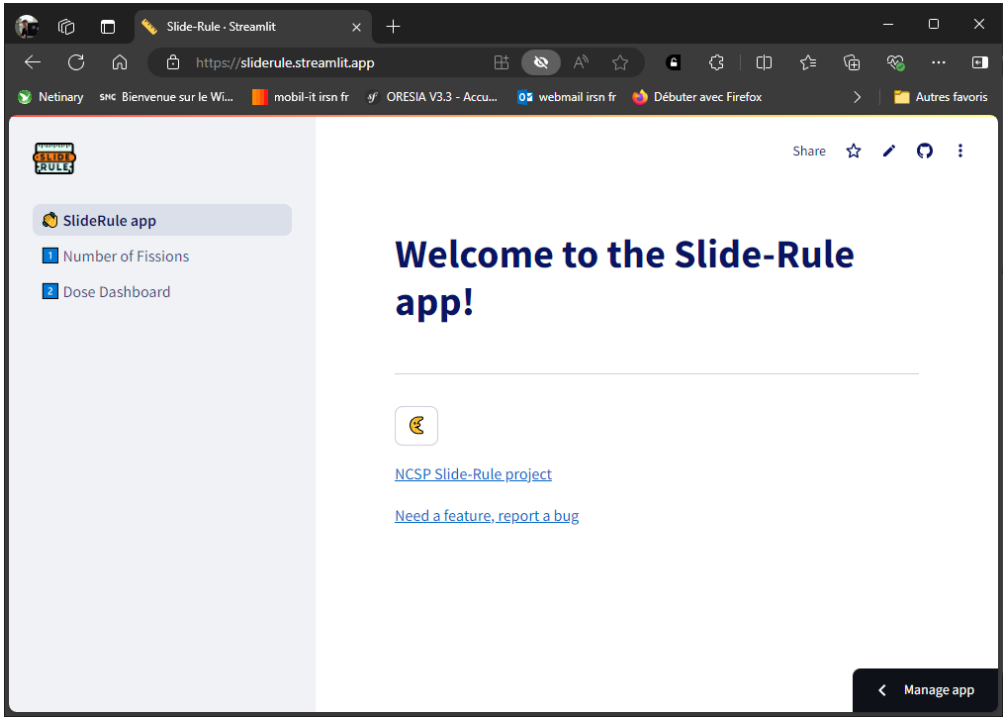
- **N and P (prompt) doses**

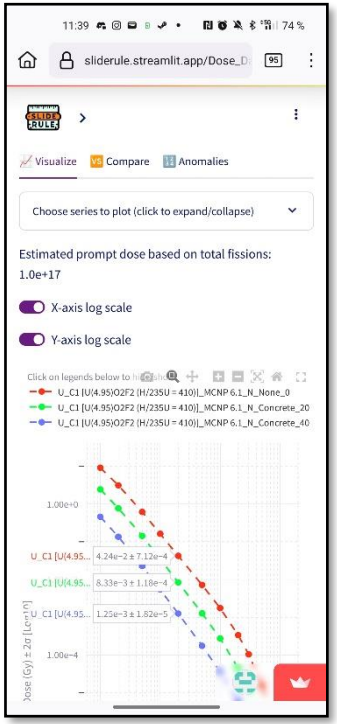




SLIDE-RULE: STATUS UPDATE

[STREAMLIT WEB APP

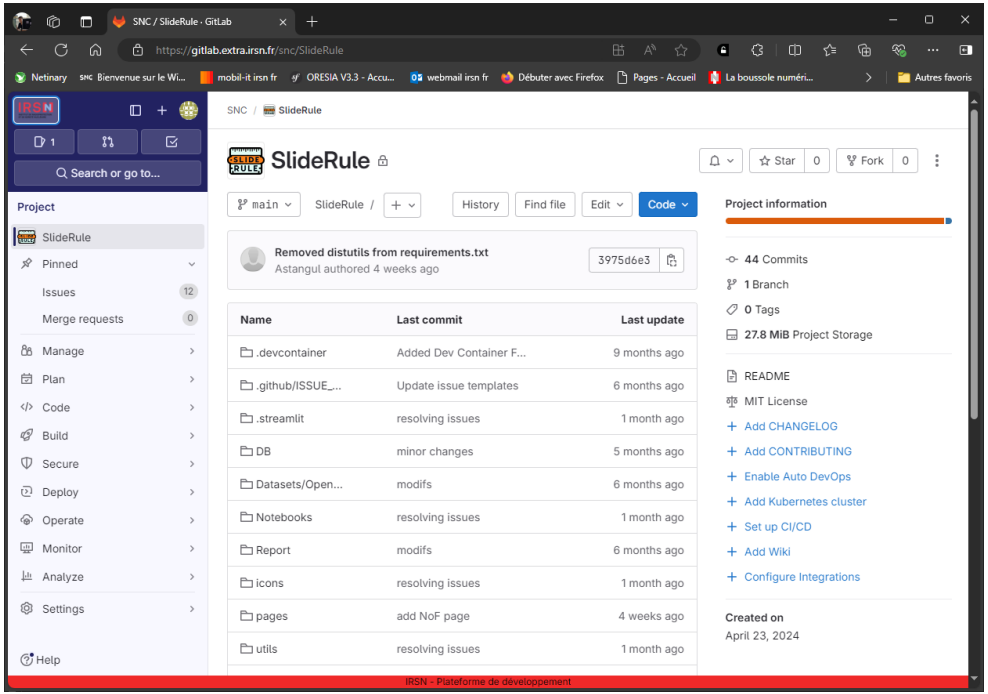




https://sliderule.streamlit.app/

SLIDE-RULE: STATUS UPDATE

[IRSN'S GITLAB



https://gitlab.extra.irsn.fr/snc/SlideRule

SLIDE RULE: DEMO-1

[WEBAPP

Calculate the number of fissions