



*Supplement of*

**The black swans of nuclear repositories – an overview of external events with a potentially serious impact on the long-term operation and safety**

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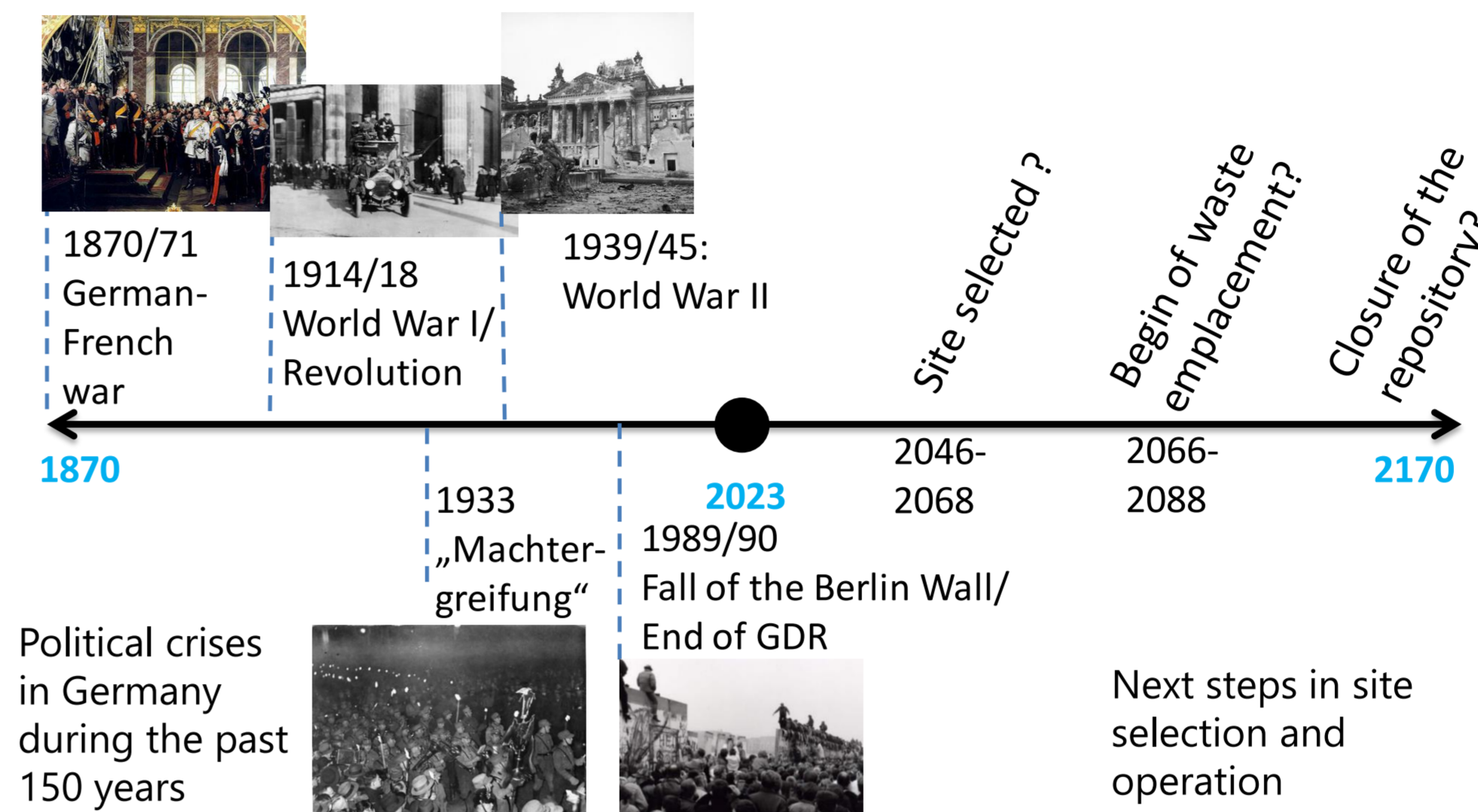
# The black swans of nuclear repositories – an overview of external events with a potentially serious impact on the long-term operation and safety

Sven Hagemann<sup>1</sup>

## BLACK SWANS IN NUCLEAR REPOSITORIES?

- In risk analysis, a black swan describes an unexpected event of large magnitude and consequences
- Events that do not specifically affect the site are typically not considered in the concept design of repositories
- However, a look at history teaches us about serious risks that should not be neglected

## A LOOK FORWARD AND BACK IN GERMAN HISTORY



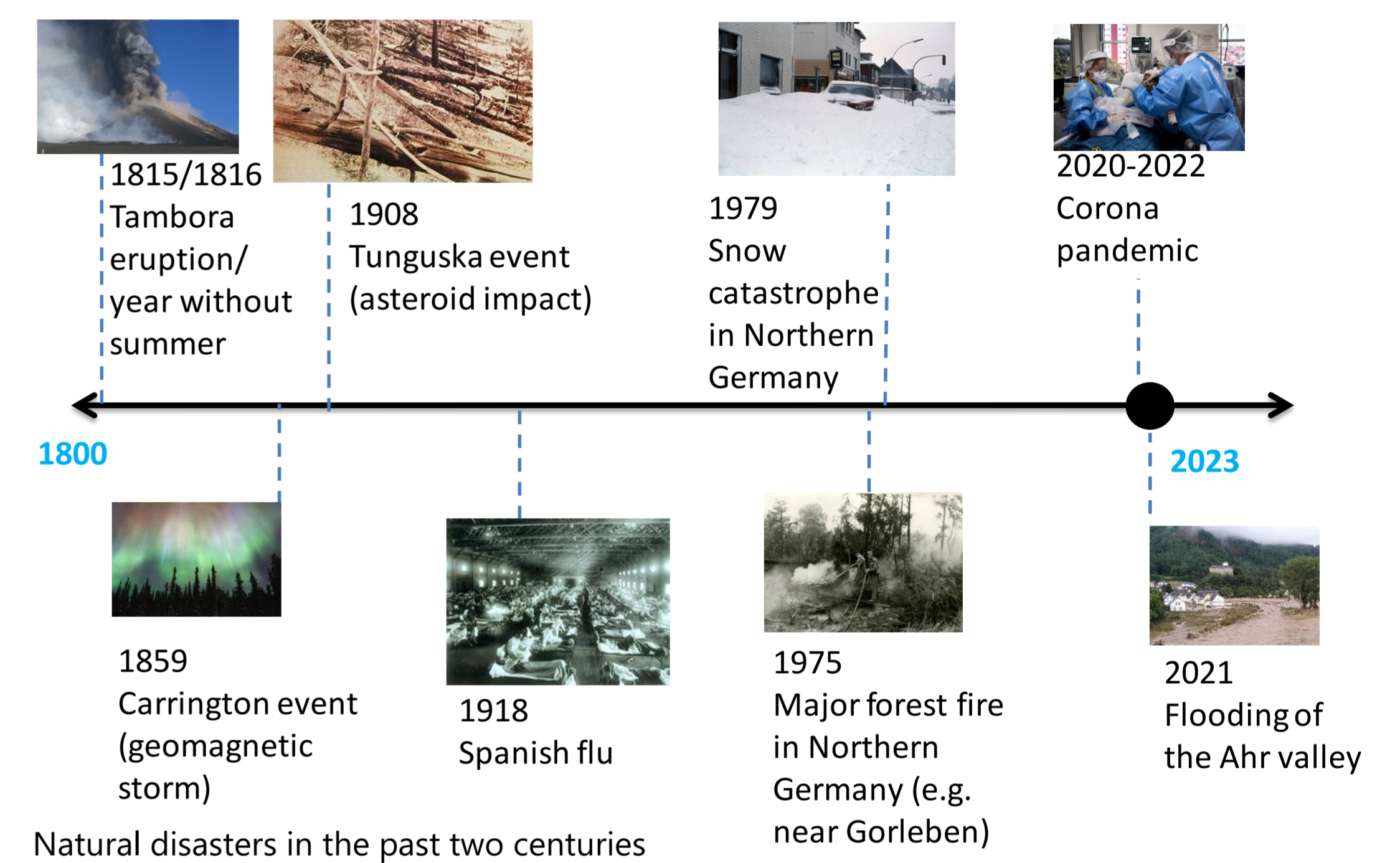
- It may need 150 years until the closure of a new HAW repository
- During the last 150 years, Germany saw three wars and two revolutions

## NOT SO UNLIKELY DISASTERS AHEAD OF US

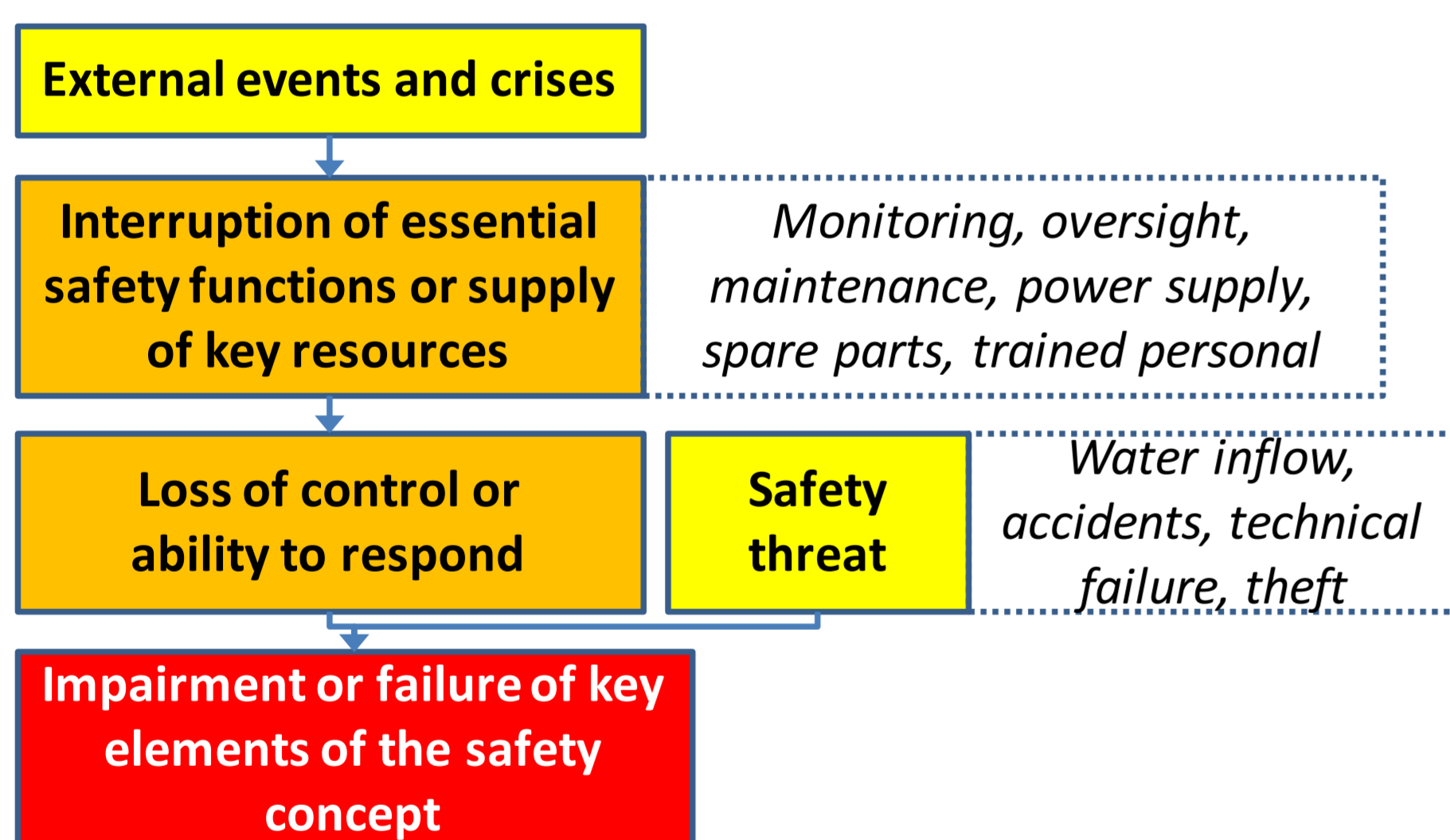
Natural or human-made disasters are events of significant probability within the timespan of a repository project. Examples are:

- **Natural disasters:** vulcanism, extra-terrestrial risks (e.g. geomagnetic storms), extreme weather events and climatic changes, large scale fires and epidemics
- **Political, economic and demographic disruptions:** wars, revolutions, economic crises, emigration, eviction, genocide
- **Technical or human failure:** organizational deficits, external accidents, negligence, corruption, system failure due to over-complexity

Indirect effects of such events are typically not considered in safety concepts



## CHALLENGES FOR THE SAFETY CONCEPT



External events may lead to scenarios where key elements of the safety concepts are compromised

## EXAMPLE ON OUR DOORSTEP: UKRAINE



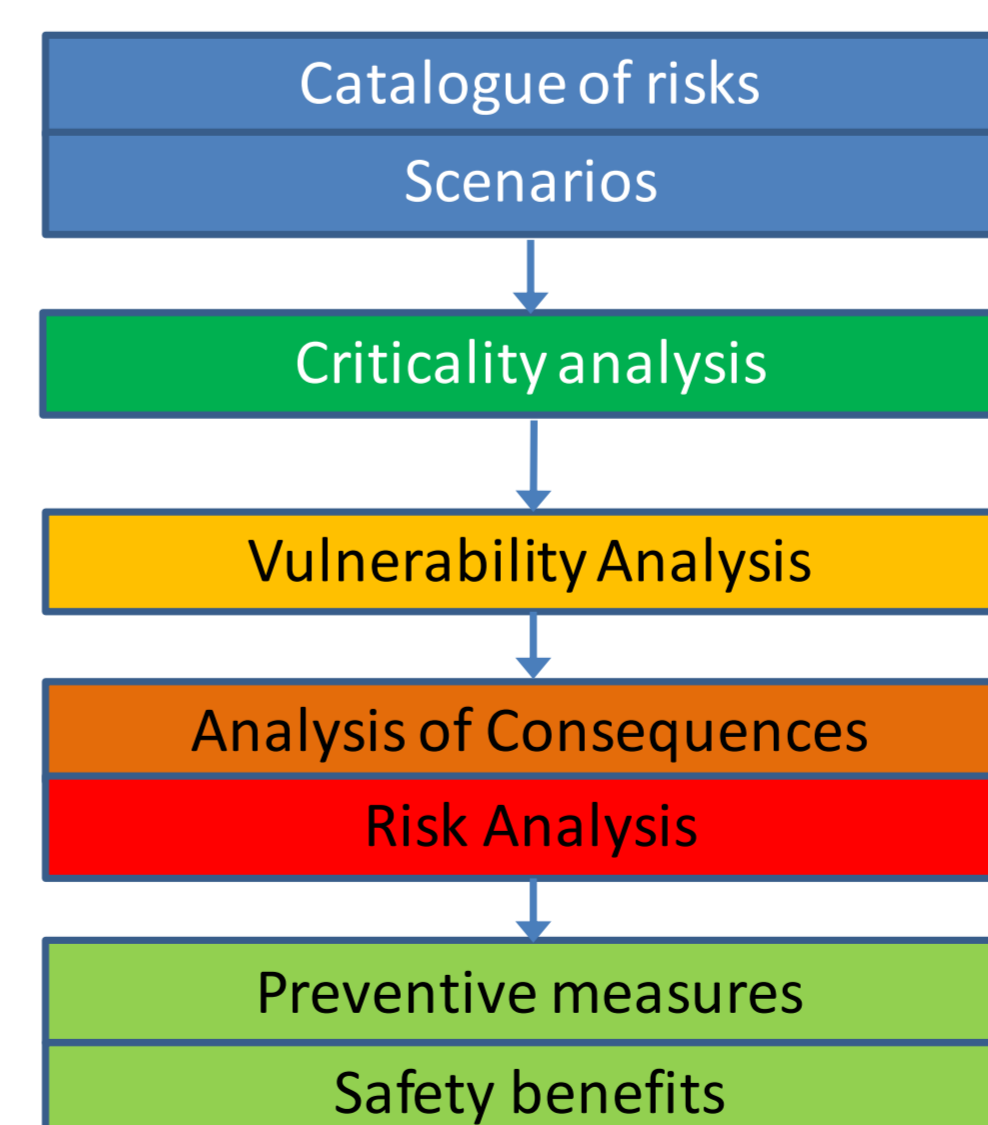
Destruction at the Soledar salt mine (Ukraine, Jan 2023) <sup>[1]</sup>

- Flooding of the Yunkom coal mine (Bunhe, temporarily occupied by Russia) a former nuclear test site <sup>[2]</sup>
- 35+ abandoned mines (2017) <sup>[3]</sup>

## CONCLUSION – PREPARE FOR THE UNEXPECTED

- The possibility of external events with grave consequences for operational and long-term safety must be taken into account
- Already at the stage of concept design, additional safety elements, measures, and processes should be included that
  - Help to manage situations of external stress
  - Provide a minimum level of safety for a certain period of time (weeks, years, decades)
  - Avoid processes that irreversibly impair the safety architecture of the repository

## FURTHER STEPS



For the development of an enhanced, resilient safety concept some further steps need to be taken, including an analysis of scenarios, criticality, vulnerabilities, consequences and risks.

### Literature

- [1] State Border Guard Service of Ukraine (2023) <https://t.me/DPSUkr/8889>  
 [2] International Centre for Defence and Security (ICDS) (2023) <https://icds.ee/en/the-harsh-reality-of-the-russian-liberation-signs-indicating-that-russia-has-committed-an-environmental-war-crime-in-donbas-since-2018/>  
 [3] OSCE (2017) [https://www.osce.org/files/f/documents/4/3/362566\\_0.pdf](https://www.osce.org/files/f/documents/4/3/362566_0.pdf).

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