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Making sense of nuclear safety: Insights from the Overall Safety Concept study

Suomalaisen ydintekniikan päivät (SYP)

October 2, 2016

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LUT, Nuclear Engineering

Why ”overall safety”?

Safety requirements and safety justification of nuclear power plants has become very complicated:

Tendency	Consequence
Increasing number of Defence-in-Depth - levels	Level independence compromised
Dissimilar postulated event and hazards	Inconsistent treatment
Multiple kinds of “safety”: nuclear safety, nuclear security, nuclear materials safeguards	Both conflicting and synergistic requirements
Gap widens between legacy plant safety features and future plant regulations	Equipment upgrading impractical if not impossible
Safety requirements developed for large LWRs only	Licensability of alternate technologies (small reactors, fast reactors) uncertain

Organised thinking in terms of an *overall safety concept* helps address such problems!

ORSAC – Overall Safety Concept framework development

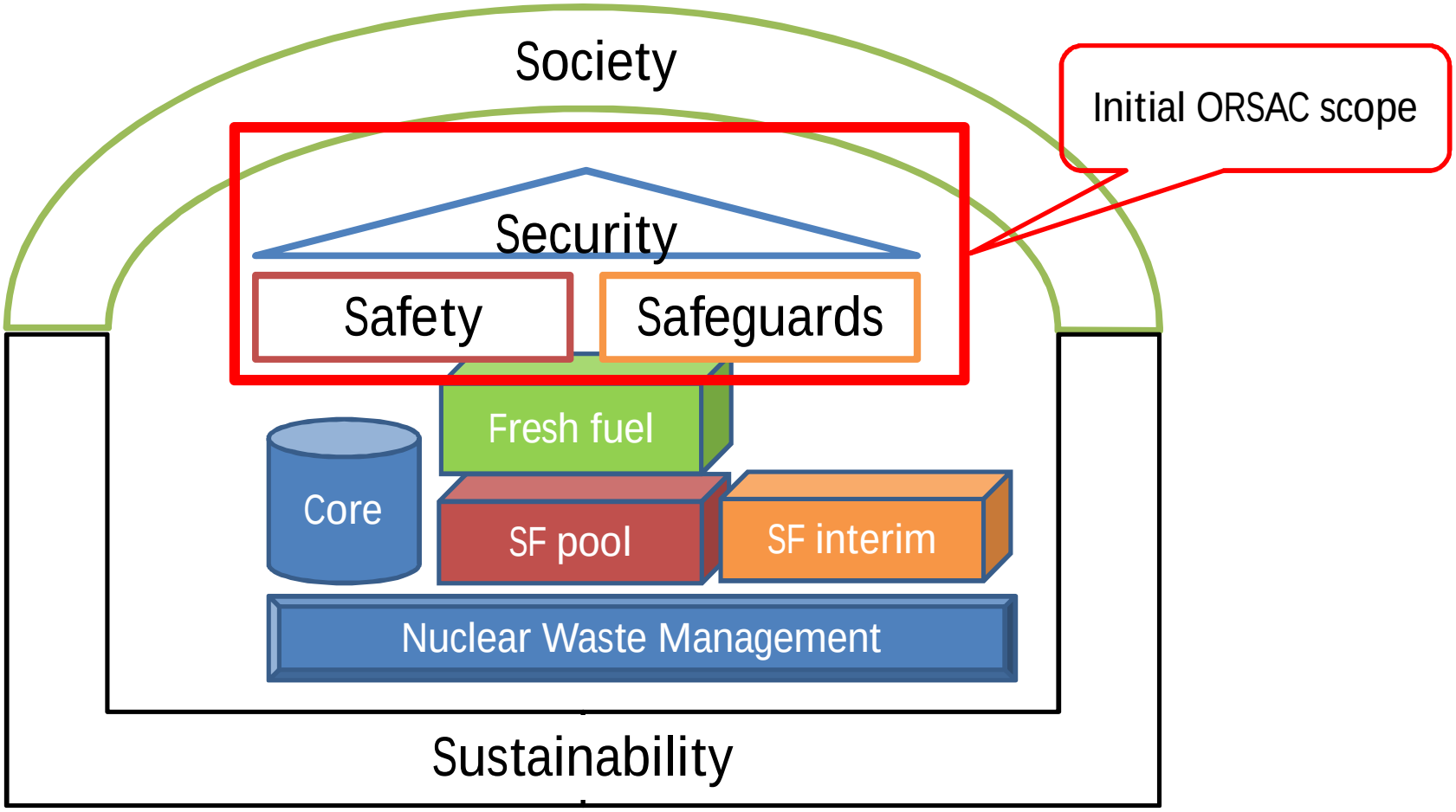
”Small study” initiated by the national nuclear safety research program SAFIR-2018 (volume 26 k€)

- topical seminar in December 4, 2015
- study launched in April 2016
- draft report produced in May-August 2016
- discussion seminar in September 2, 2016
- final report under SAFIR review

Carried out by a team at LUT Nuclear Engineering

Seminars well attended by best Finnish experts

Overall safety concept needs to cover … the whole picture [December 2015 seminar]



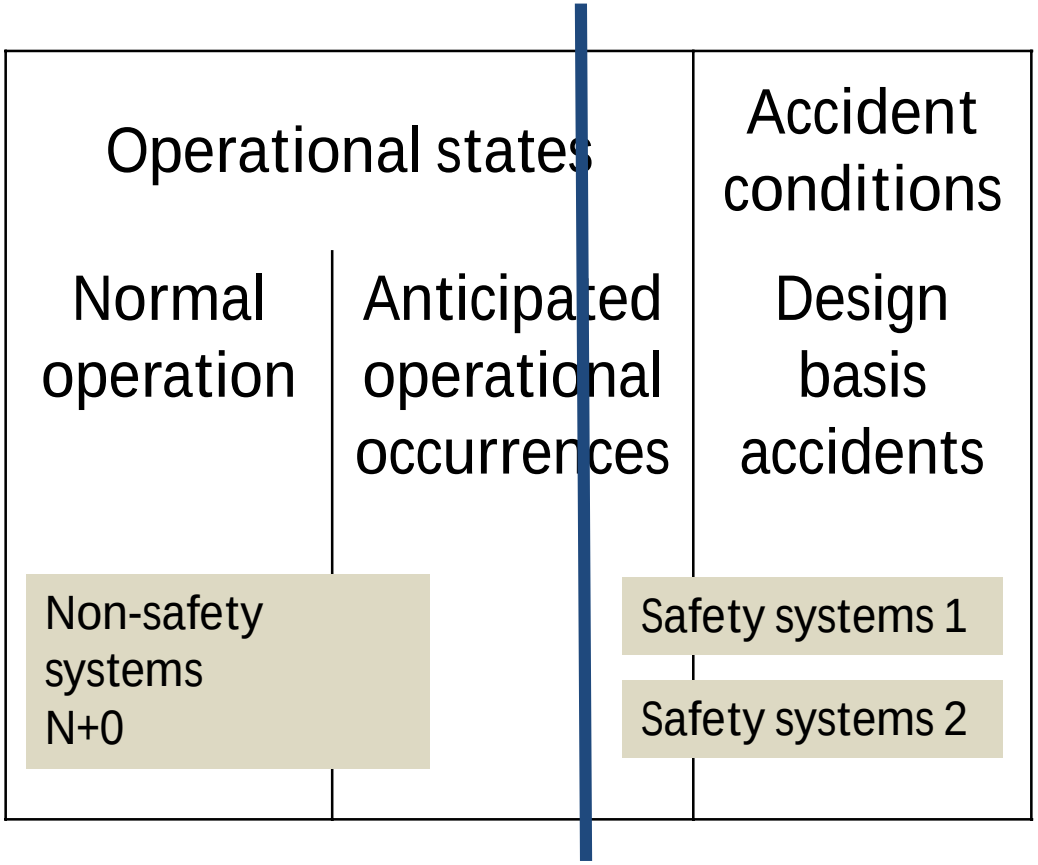
Natural starting point: defence-in-depth

Surprisingly elusive a notion

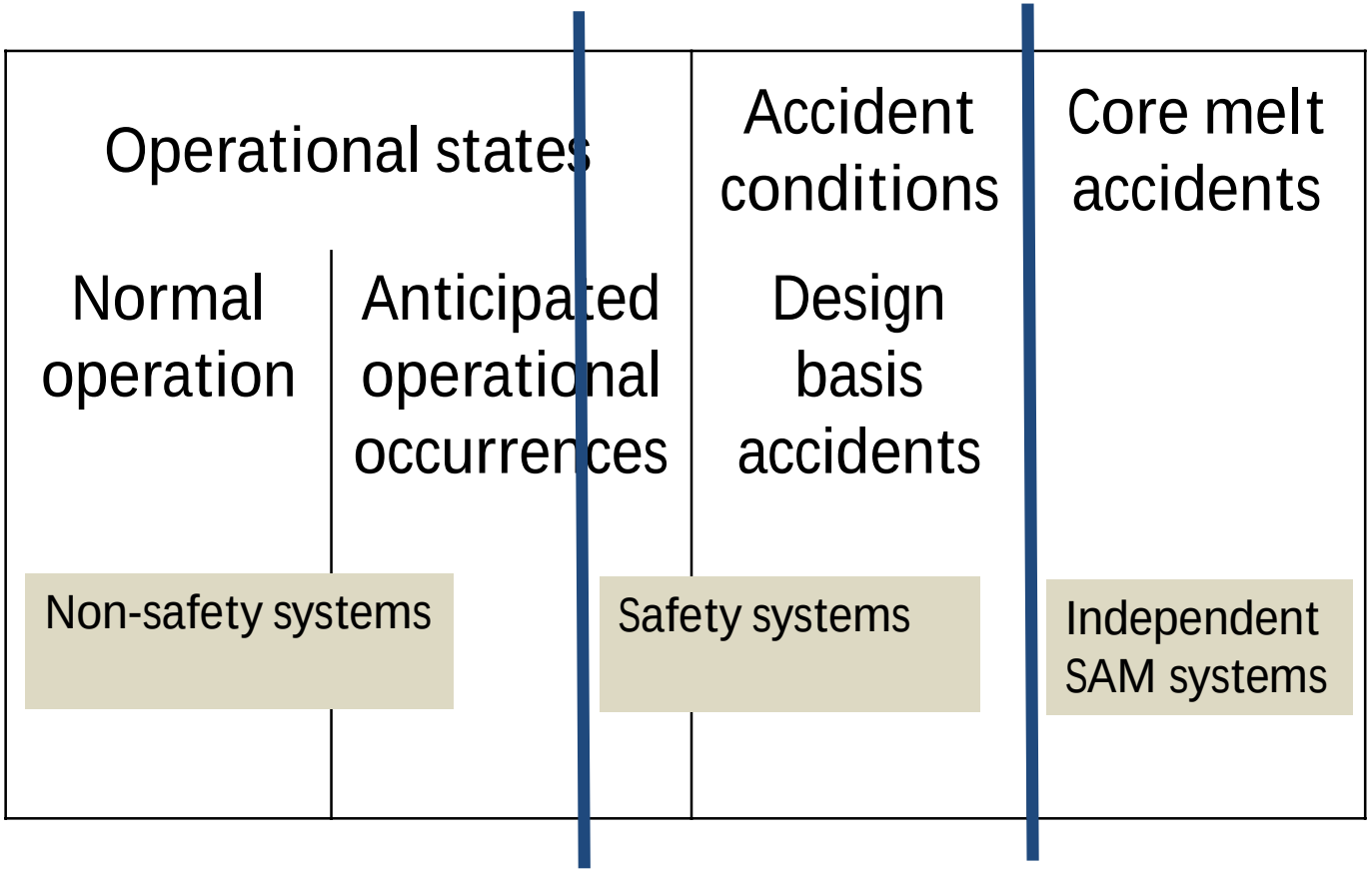
- e.g. the U.S.NRC NUREG/KM-0009, *Historical Review and Observations of Defense-in-Depth*, April 2016, contains 200+ pages of different definitions from the 1950s till present
- IAEA TECDOC-1791, *Considerations on the application of the IAEA safety requirements for the design of nuclear power plants*, 2016, gets by with 70 pages

ORSAC study builds mainly on the *functional* defence-in-depth but also uses the *structural* view

Defence levels in the 1970's

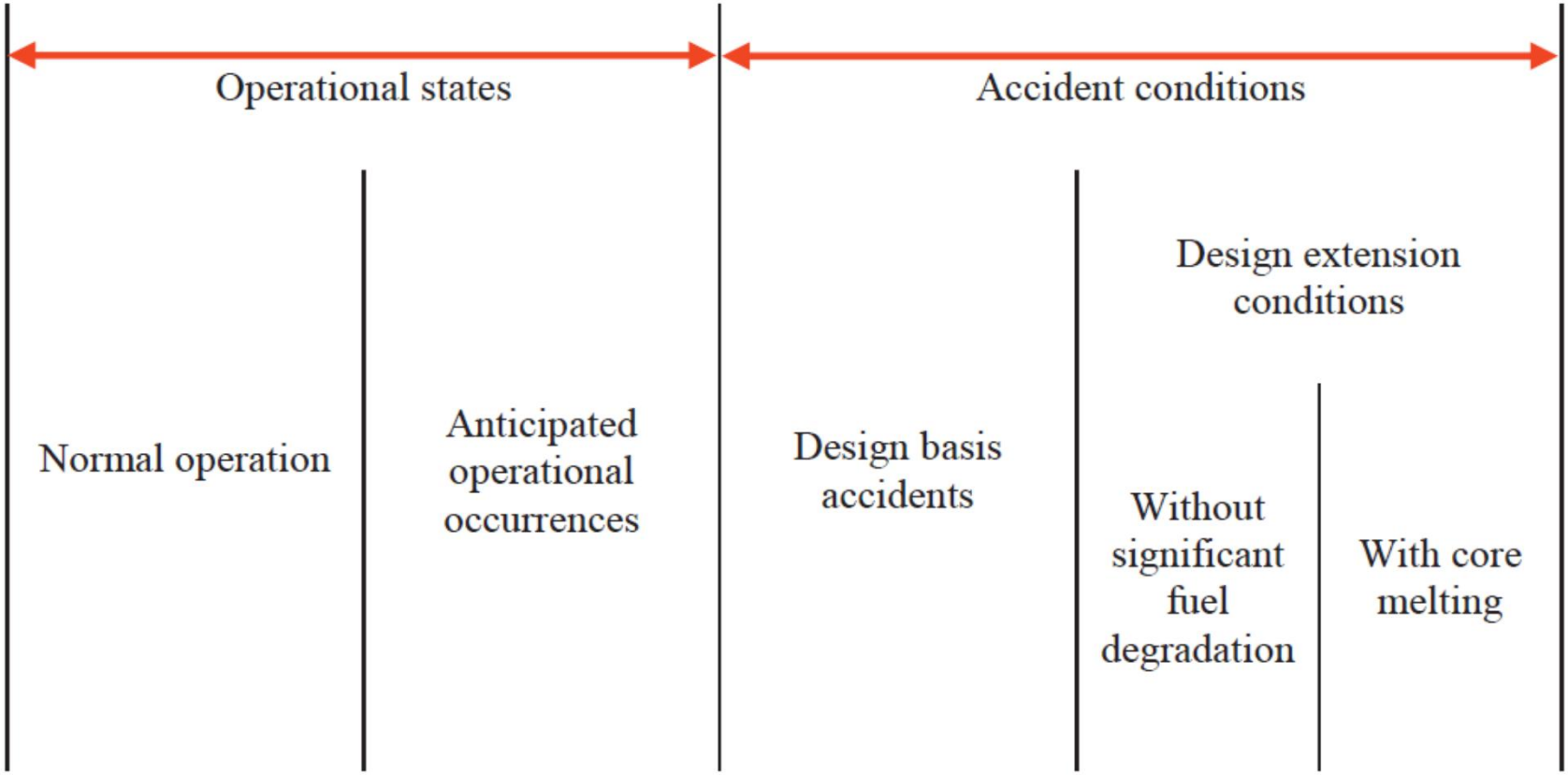


Defence lines according to YVL 1.0 1982 and VNP 395/1991

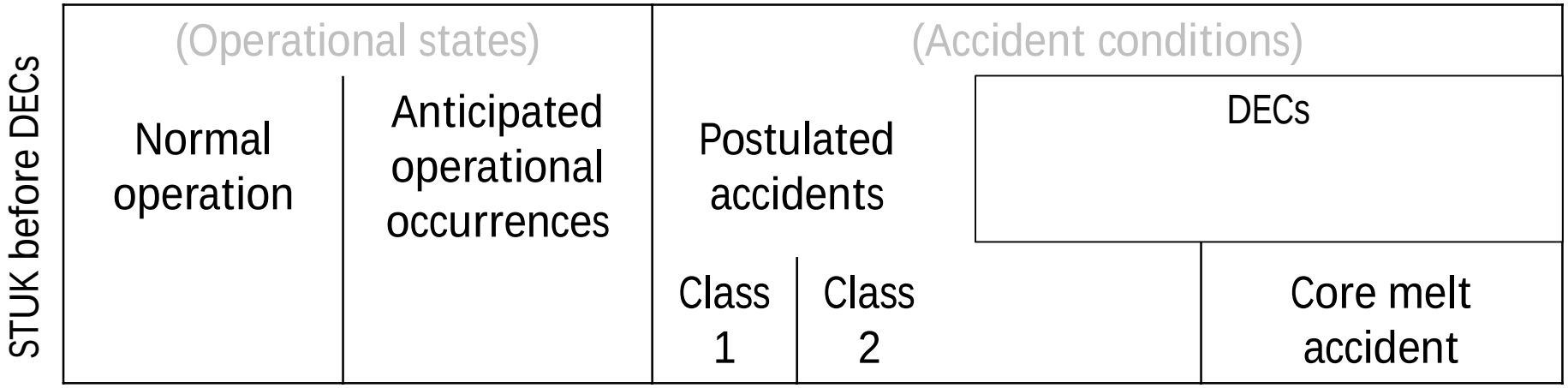


At the time SAM systems were envisioned to consist mainly of filtered containment venting, so complete independence from other safety systems was easy to achieve.

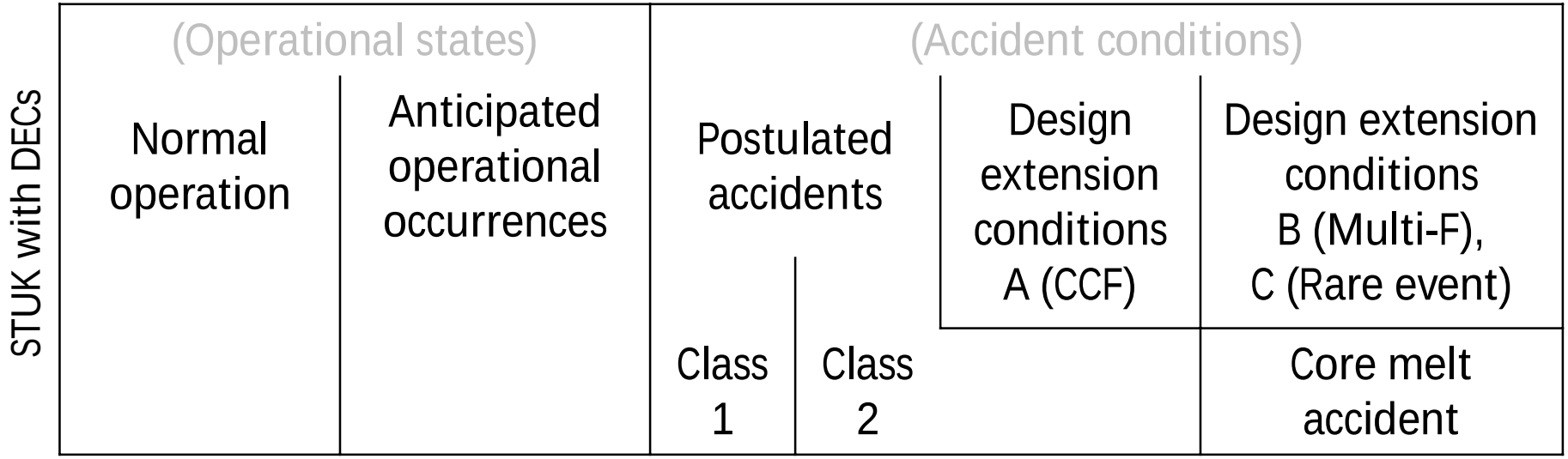
Modern IAEA view [SSR-2/1 Rev. 1, 2016]: Plant states and event categories



STUK definition of Plant states and event categories (before introduction of DECs)



STUK definition of Plant states and event categories [YVL B.1 Justification memo]



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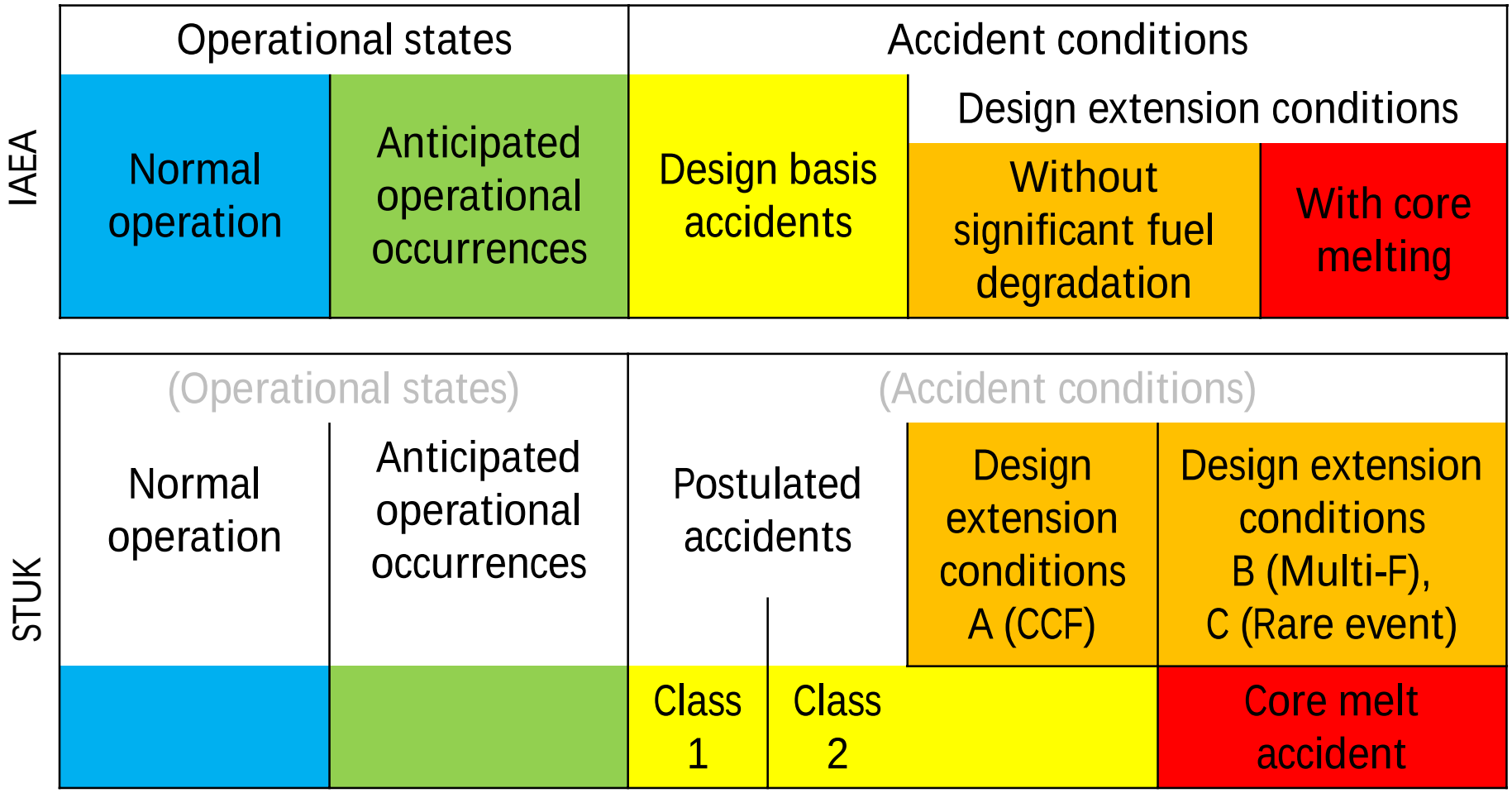
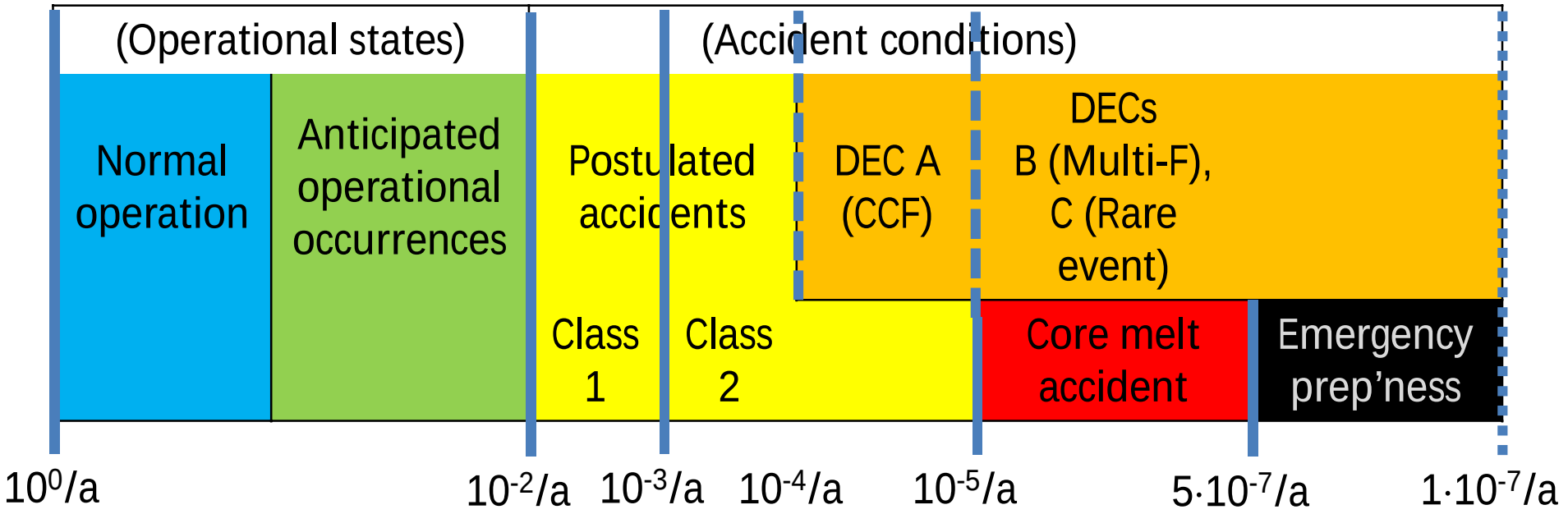


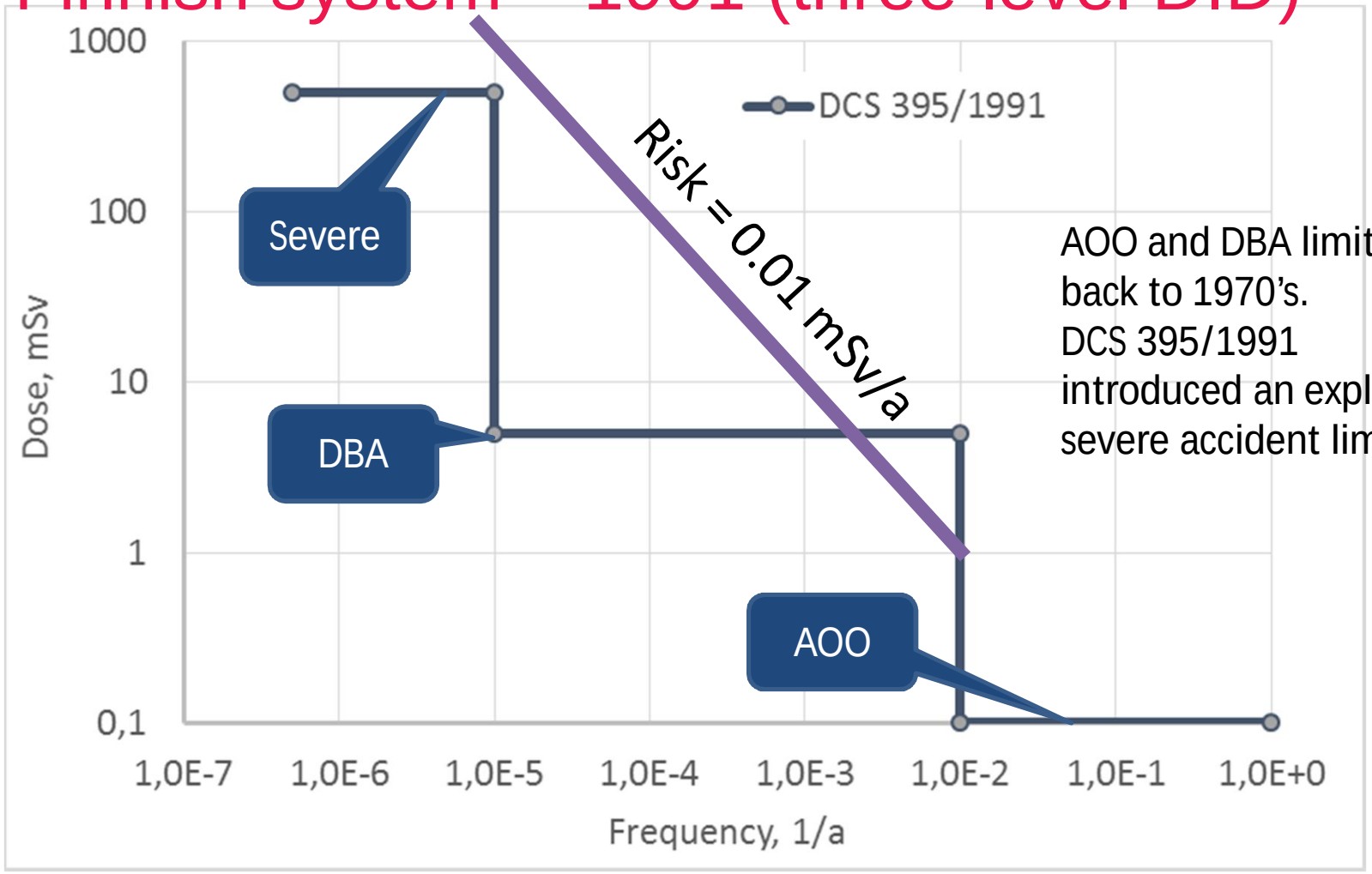
Frequency limits for event categories [YVL B.1 Justification memo; YVL A.7]



The probabilistic safety goals from YVL A.7 are CDF < 10^{-5}/a and LERF < $5 \cdot 10^{-7}$/a; these are compound frequencies. Frequency limits for DECs are indicative. Independent of their exact value, the DECs overlap the Postulated accident – Core melt – Emergency preparedness region.

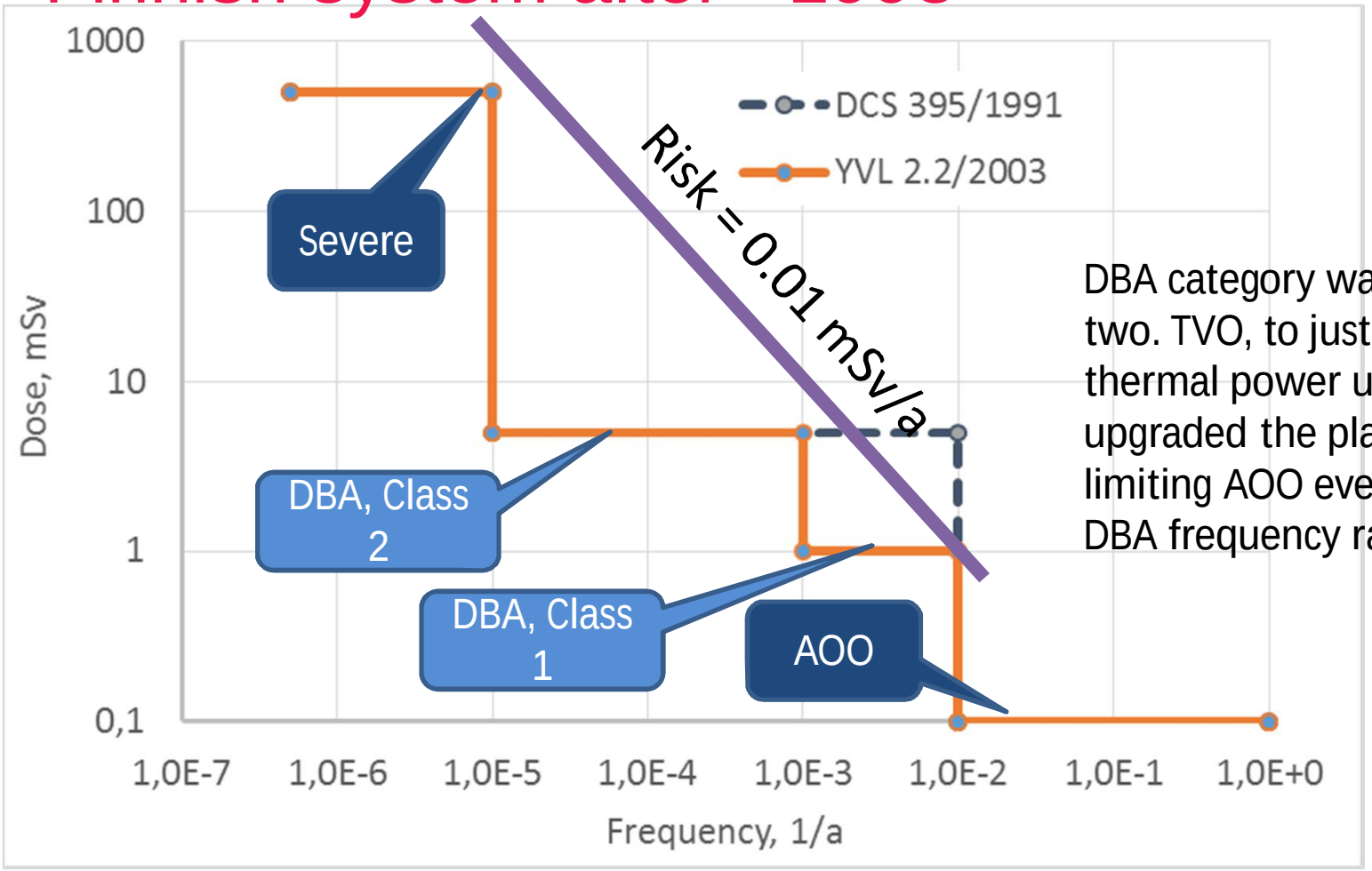
DEC C lower limit is 10^{-7}/a has been required informally, but not codified (yet?).

Dose limits and event frequencies in the Finnish system – 1991 (three-level DID)



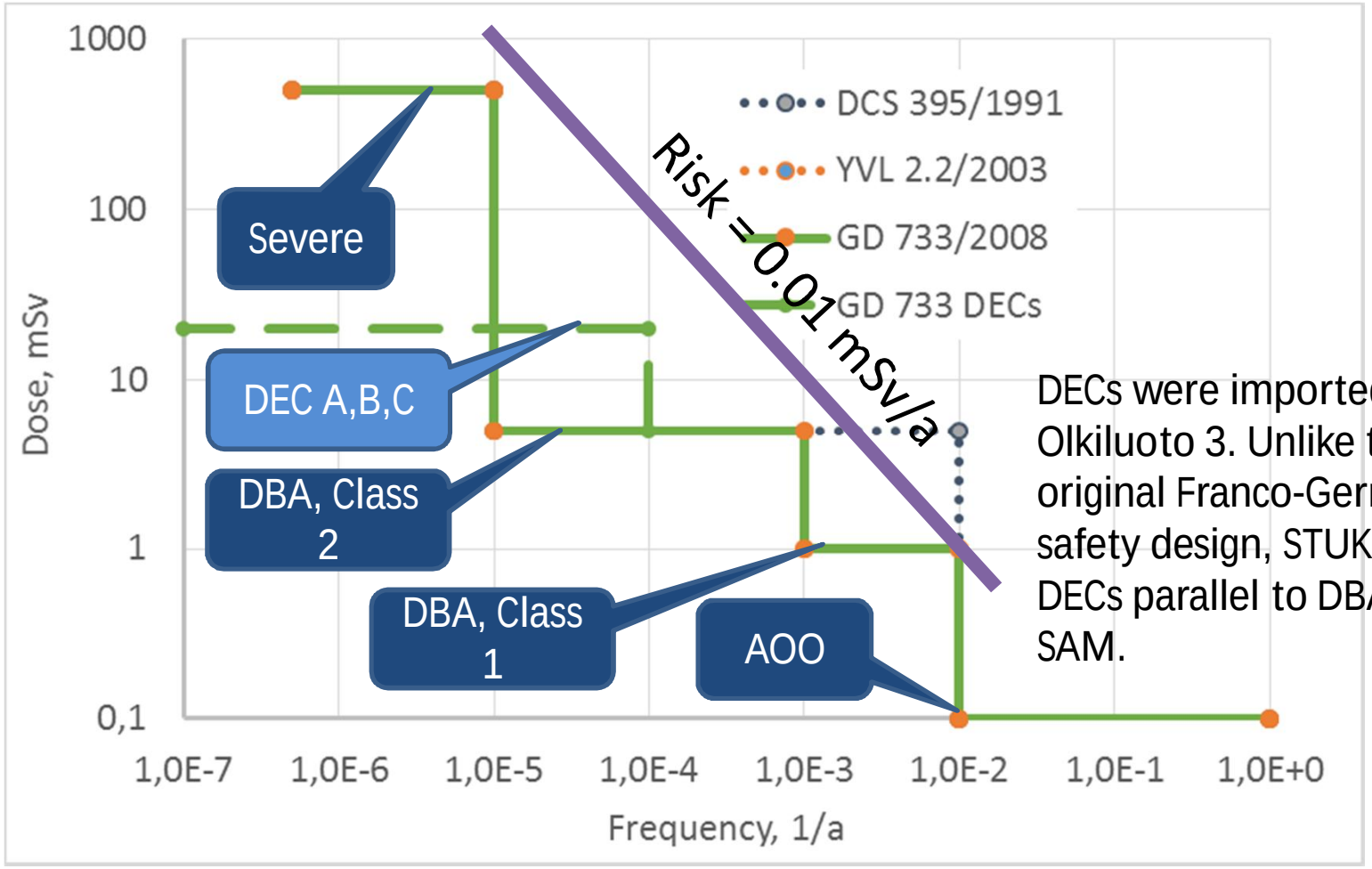
AOO and DBA limits date back to 1970's.
DCS 395/1991 introduced an explicit severe accident limit.

Dose limits and event frequencies in the Finnish system after ~1998



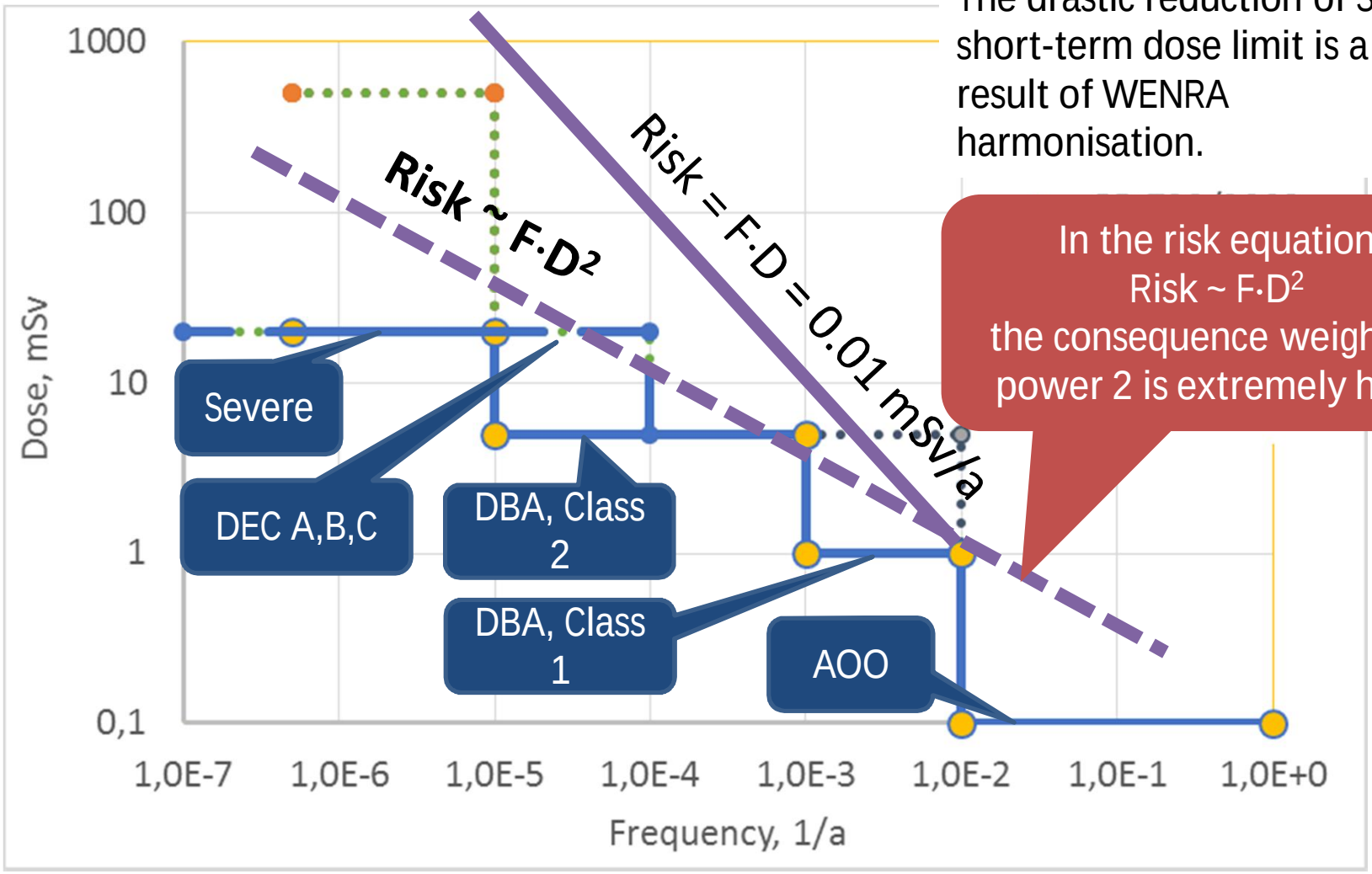
DBA category was split in two. TVO, to justify a 16 % thermal power uprate, upgraded the plant, moving limiting AOO events to the DBA frequency range.

Dose limits and event frequencies in the Finnish system after ~2008



DECs were imported with Olkiluoto 3. Unlike the original Franco-German safety design, STUK made DECs parallel to DBA and SAM.

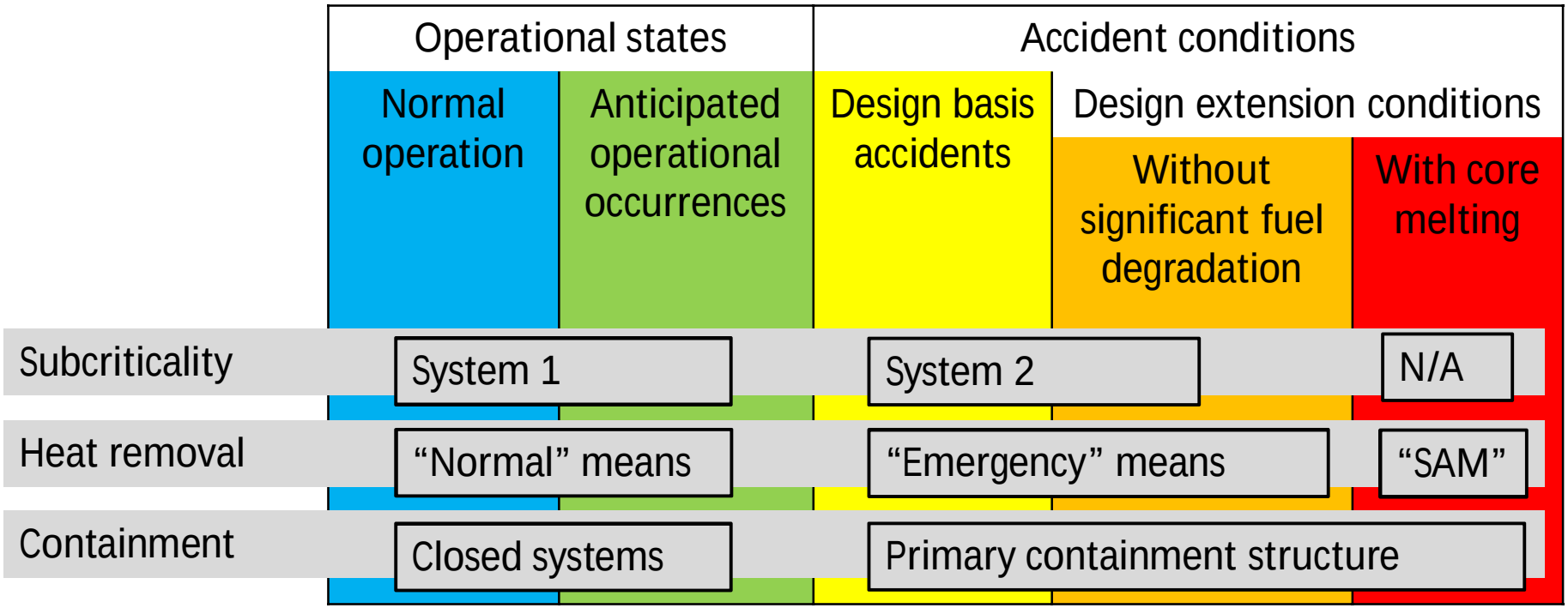
Dose limits and event frequencies in the Finnish system after 2013



The drastic reduction of SAM short-term dose limit is a result of WENRA harmonisation.

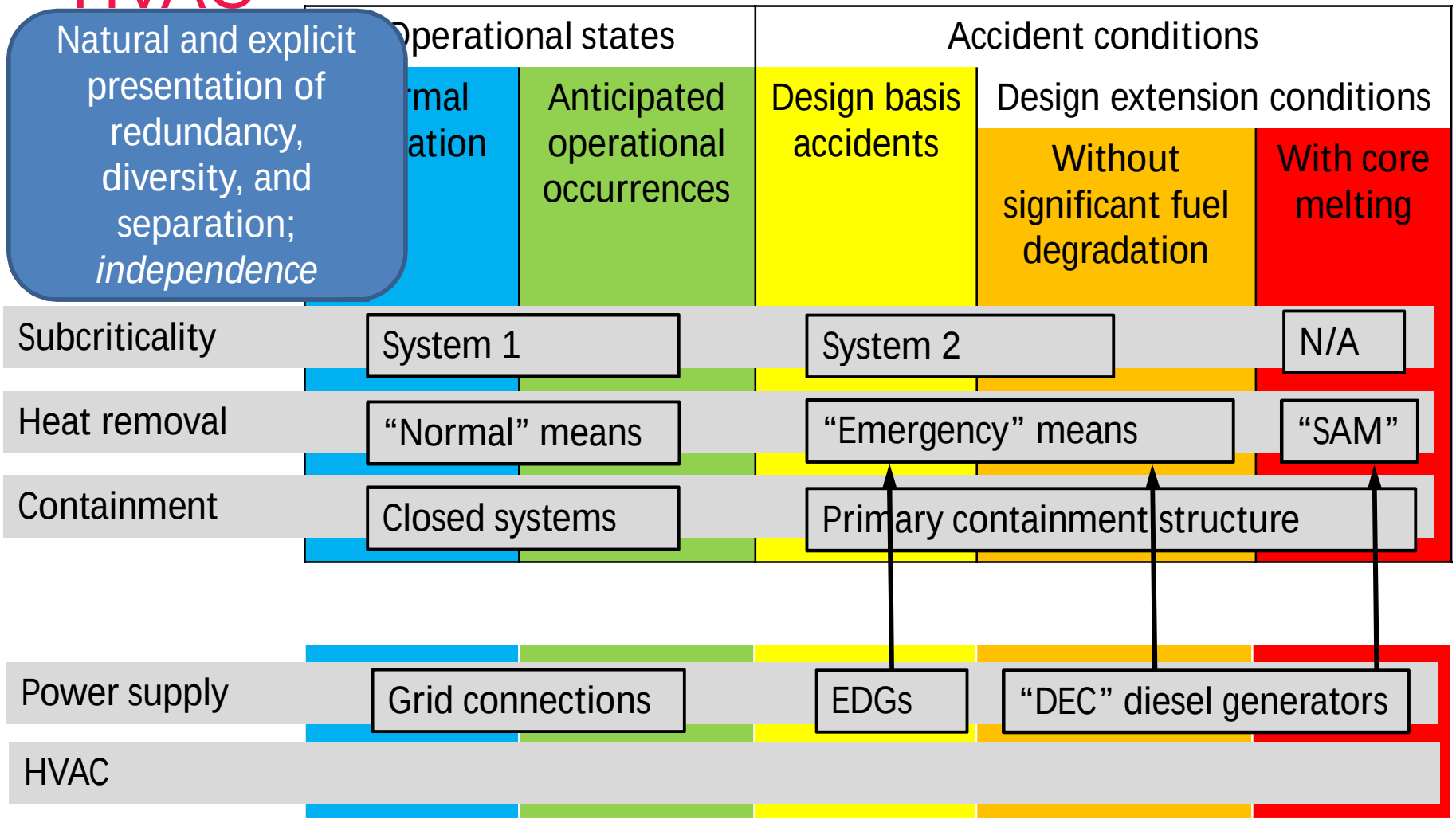
In the risk equation
Risk ~ F·D²
the consequence weighting power 2 is extremely high.

Overall concept idea: main safety functions overlaid on defence lines

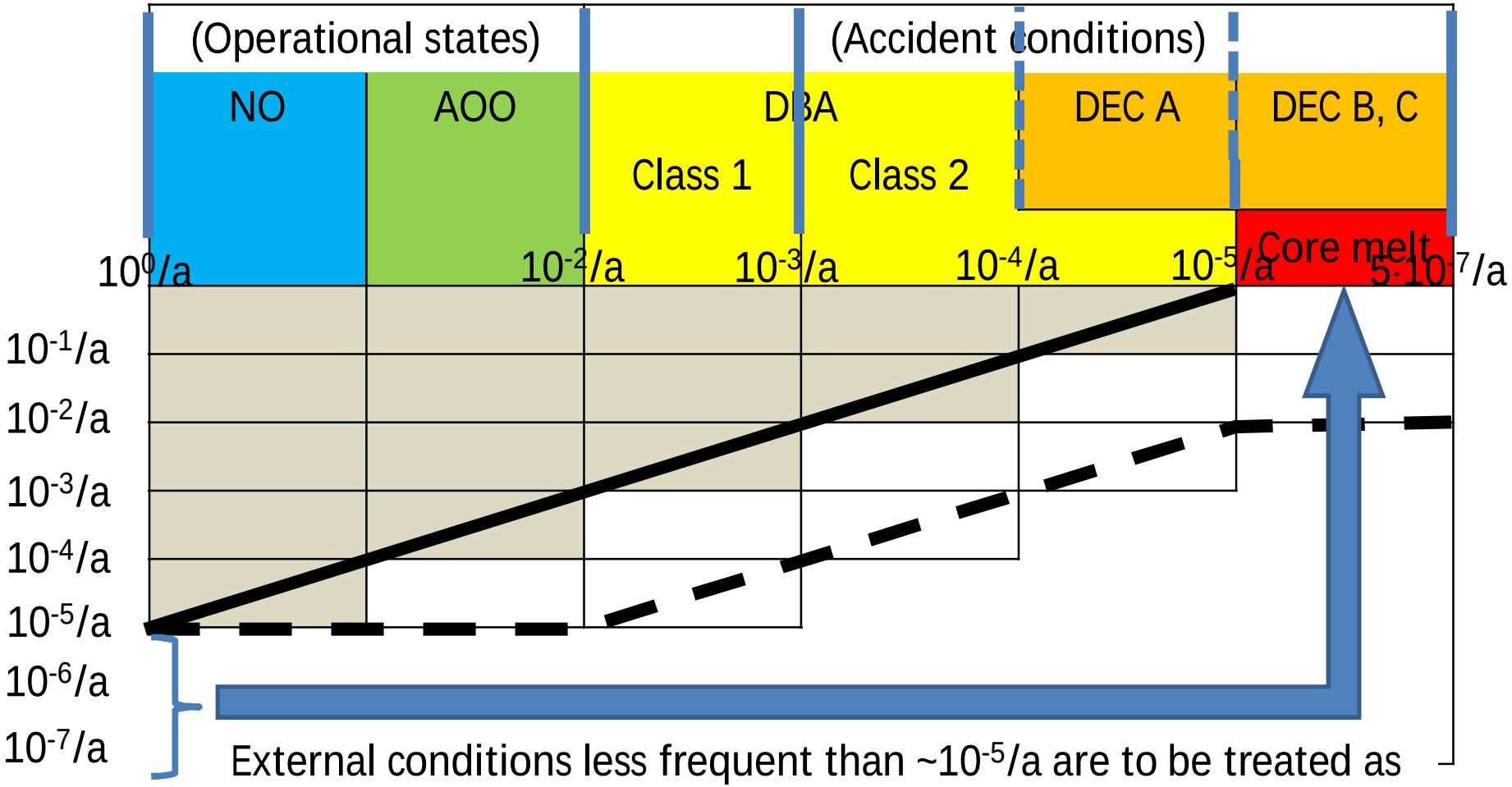


Main safety functions depend on supporting safety functions such as power supply and HVAC

Natural and explicit presentation of redundancy, diversity, and separation; *independence*

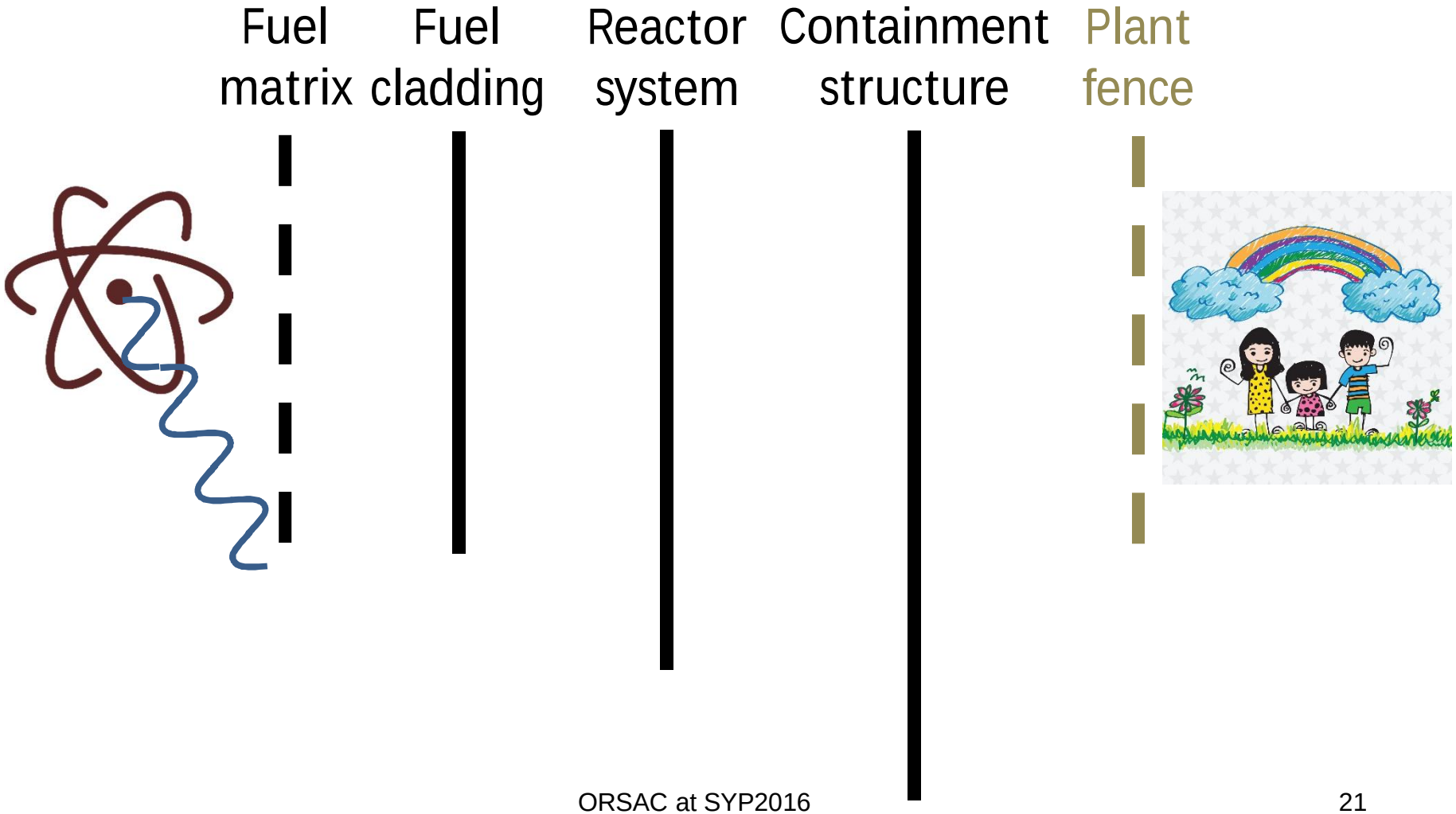


External hazard integration option

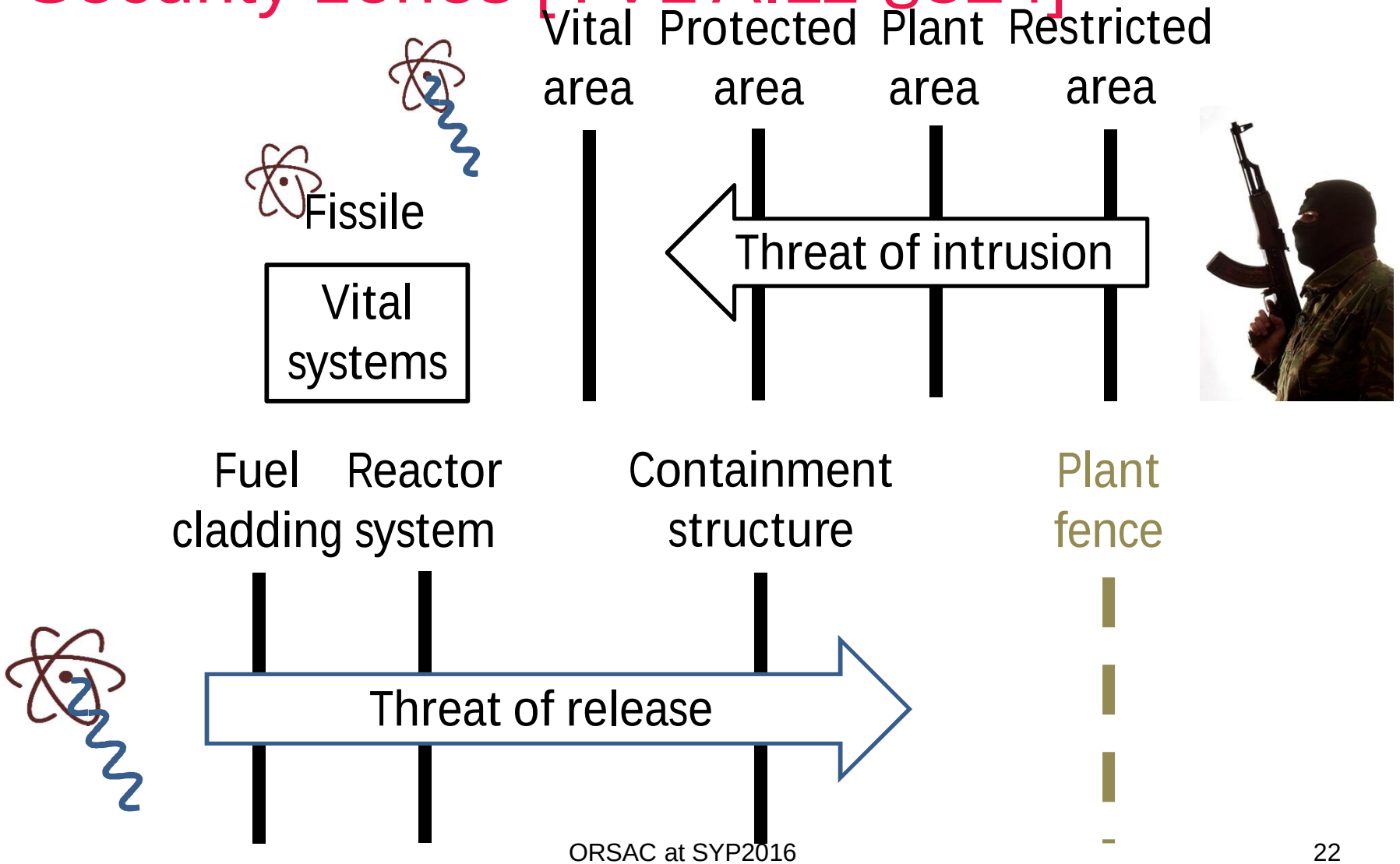


External conditions less frequent than ~10^{-5}/a are to be treated as initiating events under DEC C.

Barrier interpretation of Defence-in-Depth: against fission product release (in theory)

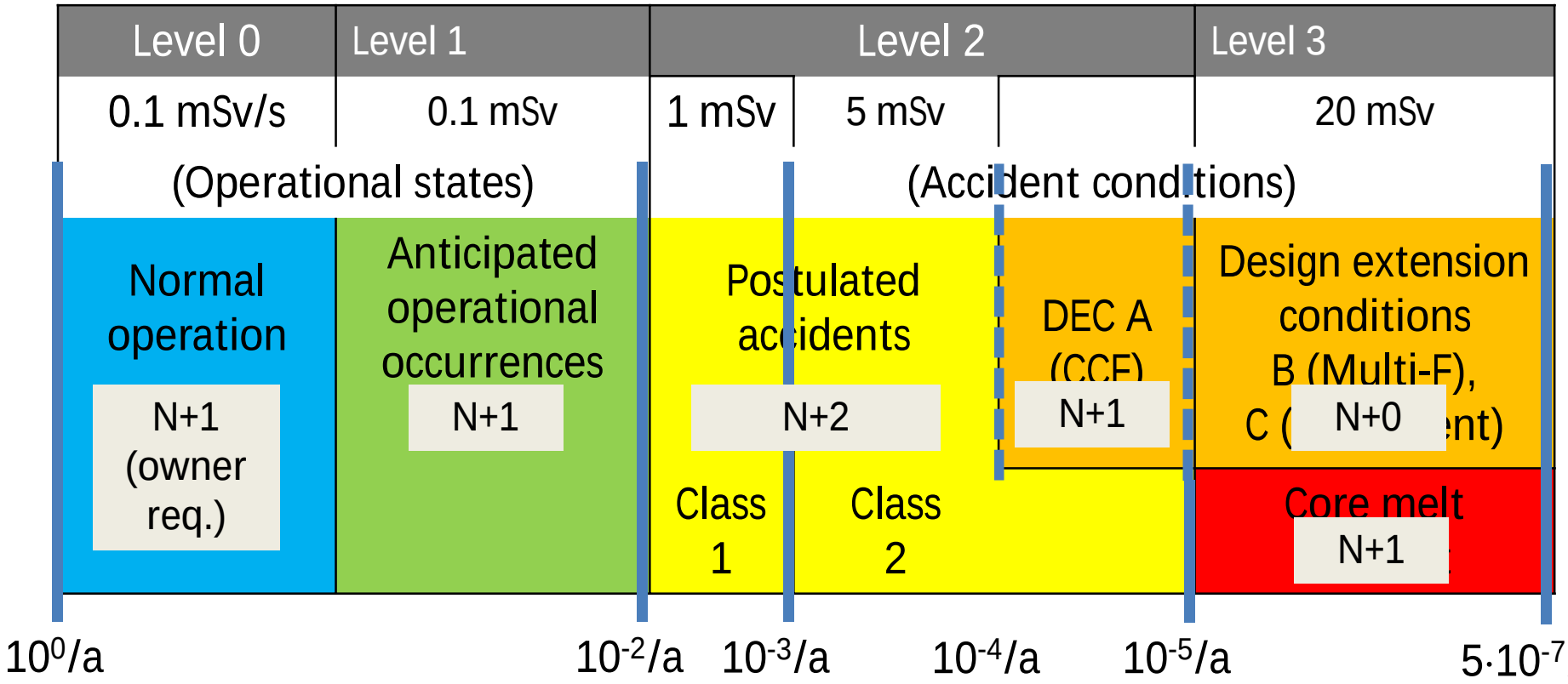


Security zones [YVL A.11 §324]

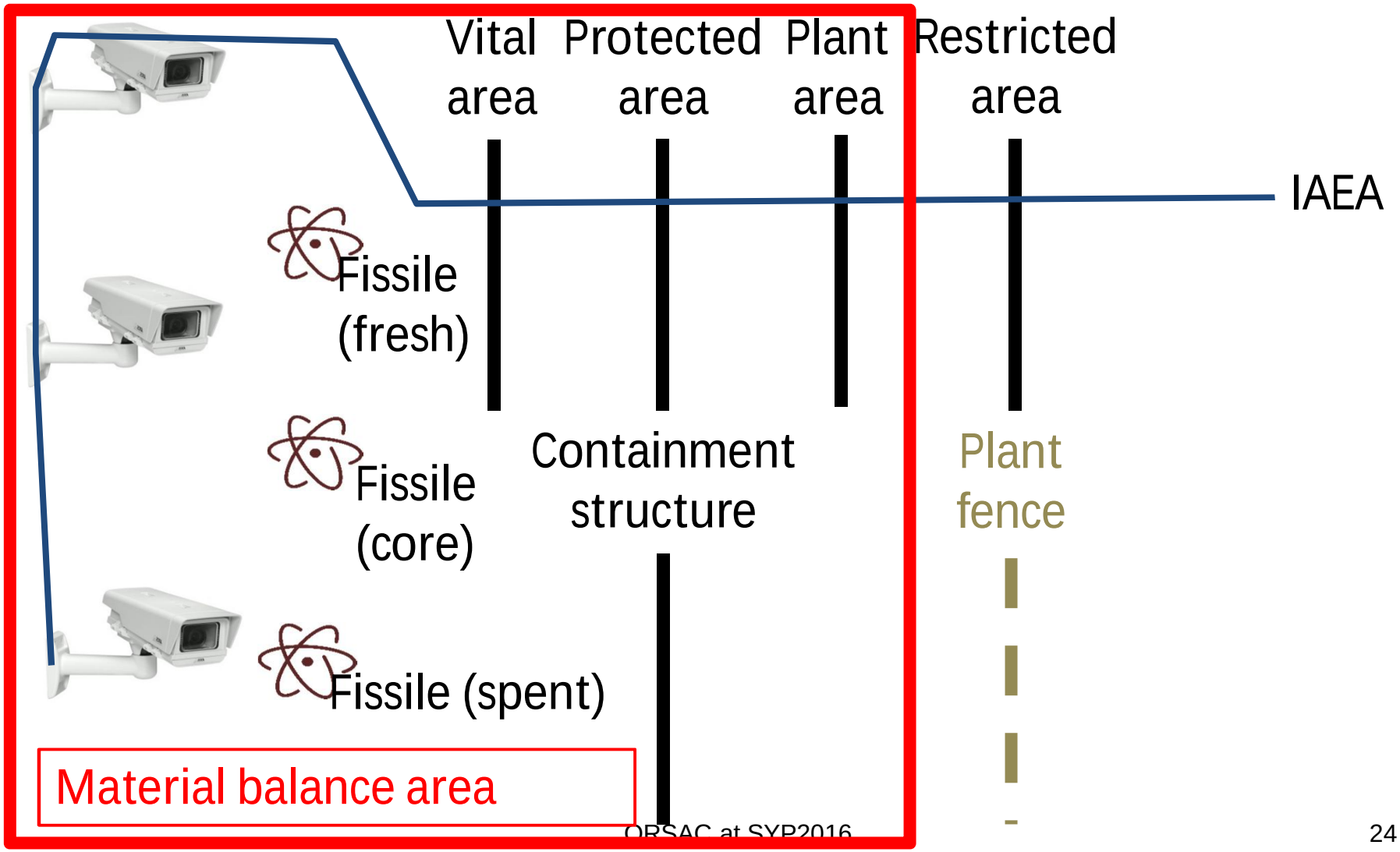


Security parallels [YVL B.1 Justification memo; YVL A.11]

The security threat levels indicate the principle, not actual levels.



Safety, security, safeguards integration



Organisation of organisations – new build

Functional Level	1 Construction	2 Ownership	3 Technical oversight	4 Administration	
				By law	By opinion
Organisation	Constructing consortia (CFS, RAOS)	Project owners (TVO, Fennovoima)	Technical Regulator (STUK)	TEM / Govern-ment	Parliament
Support / Stakeholder	Expert services by TSOs, universities				
	Inspection Organisations (independent)		IOs, accredited	Intervenors	
	O&M contractors			Local population General public	

Conclusions and future avenues

ORSAC has successfully produced an Overall Safety Concept that can

- make sense of Defence-in-Depth and factual independence of defence lines
- naturally and logically integrate initiating events and various hazards, up to security and safeguards hazards

The concept is transparent – all assumptions are made visible – and forces the user to maintain an overall view in sight at all times

Conclusions and future avenues

Many paths for future development:

- practical application to an operating plant
- extension to equipment qualification and justification
- deepening the security and safeguards treatment
- deeper treatment of safety margins at individual levels
- deeper analysis of nuclear community as an organisation-of-organisations
- extension to fresh and spent fuel storages and waste disposal
- application to an SMR or GEN4 concept

Thank you!

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