

# Conservatism in Safety Cases

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# Purpose of this presentation

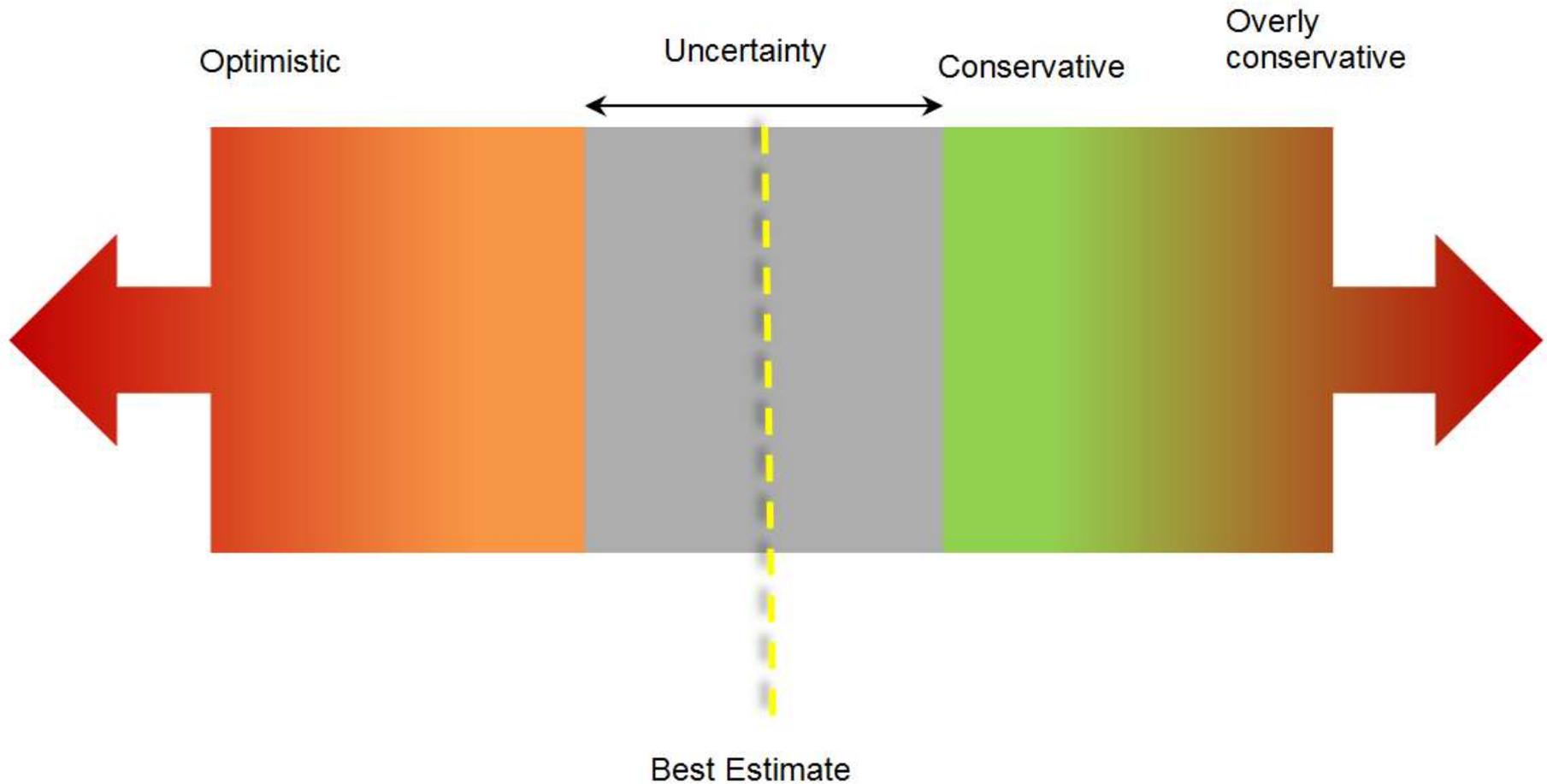
To help safety case practitioners (and others):

- to explain the role of conservatism in addressing uncertainty in nuclear safety cases
- to help safety case practitioners
  - be aware of conservatism, and the potential effects of getting the level of conservatism wrong; and
  - to use conservatism when it is required, and to achieve a balance between under-conservatism and over-conservatism

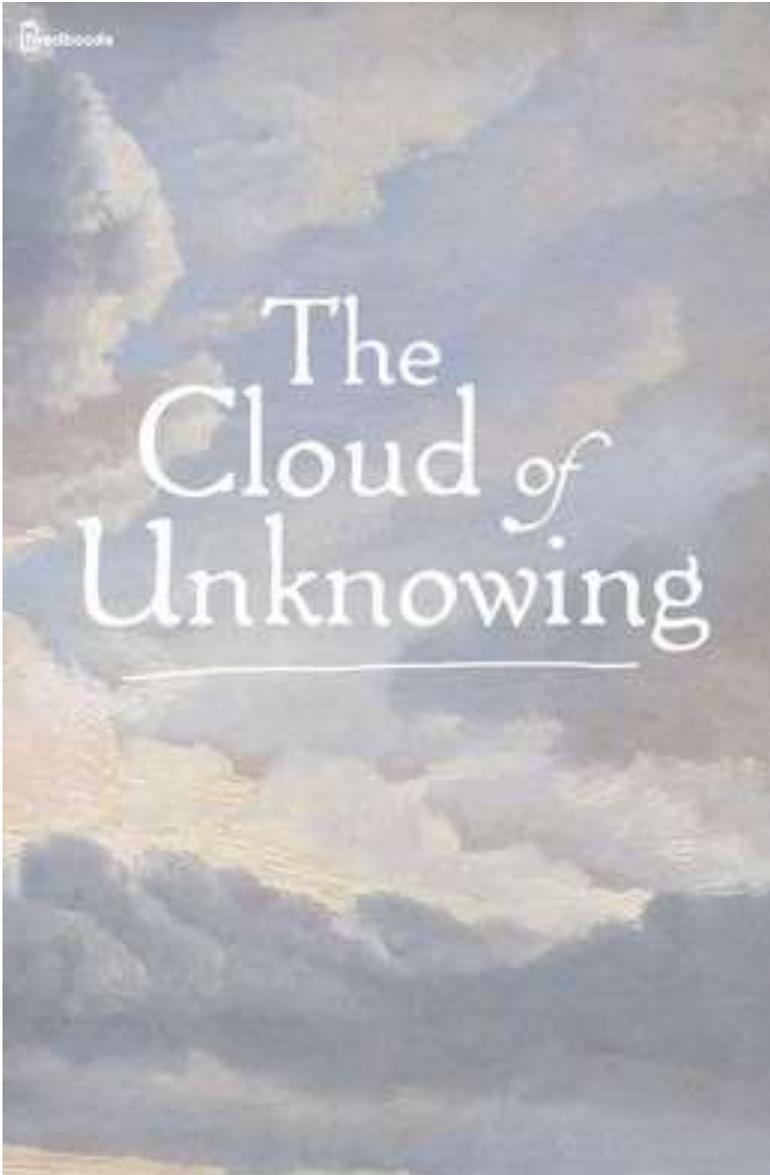
# Uncertainty and conservatism (1)

- In nuclear safety cases, there is a specific methodology called Design Basis Analysis (DBA)
  - DBA is a deliberately conservative technique
  - The purpose of the conservatism is to address uncertainty
  - Values chosen do not have to be worst-case
    - but it should be clear that the safety measures can cope not just with what might be expected in an accident, but also reasonable variations in accident development
  - Nuclear safety assessors have been using DBA for decades, but it's still tricky to get the level of conservatism right...

# Uncertainty and conservatism (2)



# Uncertainty and conservatism (3)



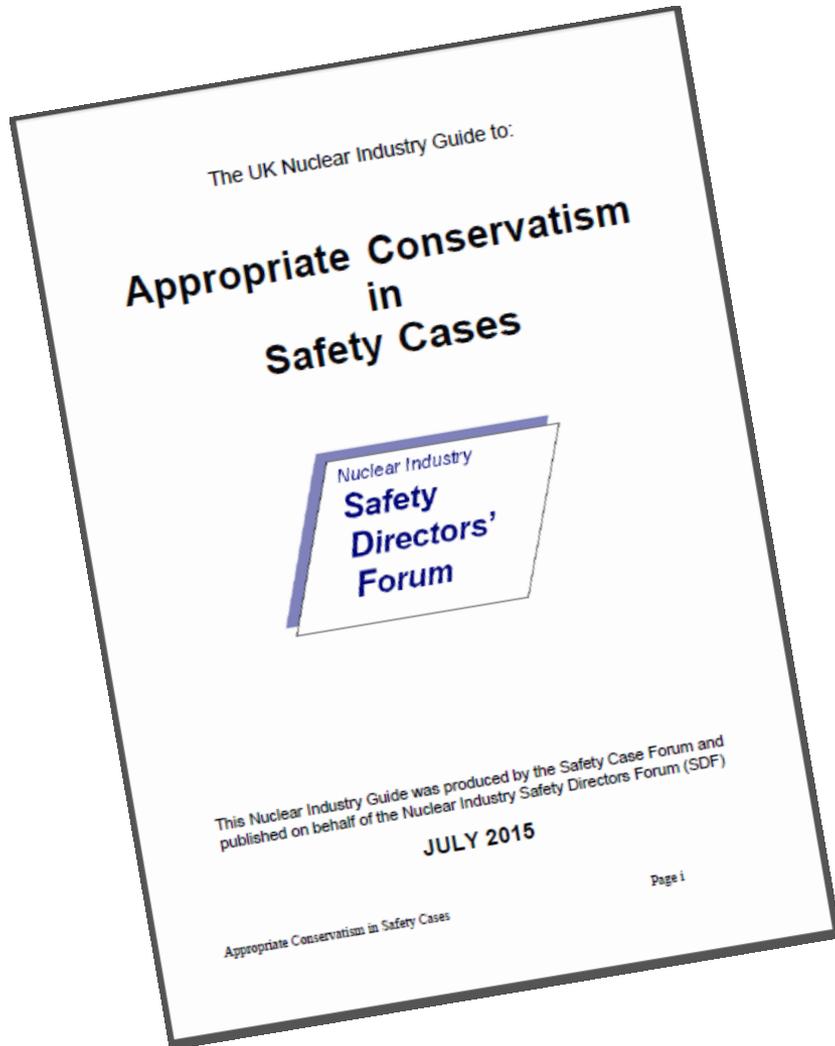
# Why is conservatism important in safety cases?

- An under-conservative safety case might under-specify safety measures
  - e.g. under-specifying the height of a tsunami wall
- An over-conservative safety case
  - is larger and more complex than necessary
  - identifies many shortfalls that don't seem to be credible
  - is unexpectedly expensive

# Acknowledgements (1)

- ARCADIS were asked to author a Safety Case Forum Guide on appropriate conservatism
  - the Safety Case Forum (SCF) is a UK-wide body that reports to the UK nuclear industry Safety Directors Forum
  - the SCF has safety case representatives from nuclear licensees, authorisees and other nuclear organisations
- The Guide's production was funded by Low Level Waste Repository Ltd (LLWR).

# Acknowledgements (2)



- The Guide has now been published on the Nuclear Institute website: [Appropriate Conservatism SCF Guide](#)
- This presentation is partly based on that SCF Guide, with grateful acknowledgements to all who contributed

# What is conservatism?

- In safety analysis, conservatism is an approach where the use of models, data and assumptions would be expected to lead to a result that bounds the best-estimate (where known) on the safe side
  - the above definition assumes 'best-estimate' is understood
- Best-estimate in this context is taken to be the arithmetical mean
- A conservative estimate is not necessarily the 'worst case'

# Why do nuclear safety cases adopt a conservative approach?

Either

- to address uncertainty
  - a requirement of Design Basis Analysis in the Office for Nuclear Regulation's (ONR's) Safety Assessment Principles (SAPs); or
- for convenience

In either case, authors should make it clear that a conservatism has been used, and why

# Impact of over-conservatism on safety

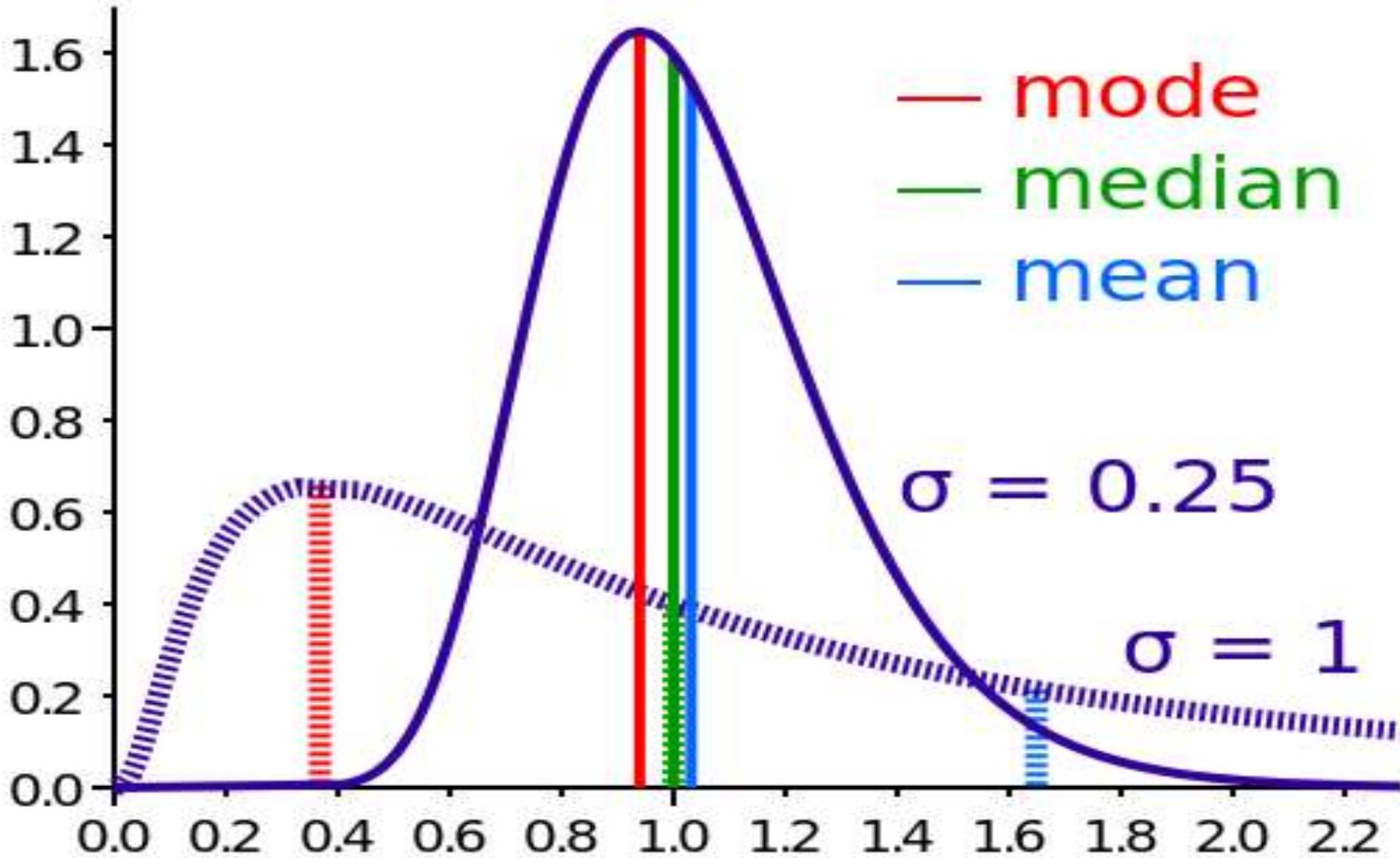
- The use of a conservative methodology may be so conservative that important safety issues may be masked
  - a serious effect!
- Decommissioning might be delayed unnecessarily
  - but decommissioning is the main way to reduce nuclear hazard and risk

Thus over-conservatism, as well as under-conservatism, *can be* the enemy of safety!

# Why are some safety cases over-conservative?

- The effect of combining individual conservatisms is not just cumulative; it can be **multiplicative**, resulting in major over-estimates in assessed results
  - this can happen *without the knowledge of the analyst*

# Log-normal distributions



# An example of over-conservatism

- Radiation dose rate from fuel being on a ramp (related to a fault condition) was over-estimated
  - a new interlock was installed as a result
- Testing was carried out by bringing fuel up the ramp
  - but the door to the area could still be opened, allowing operator access
  - failure of the installed system? No!
- Result: safety case process in disrepute!

# Key areas of a safety case for over-conservatism

- Design
- Fault progression
- Consequence assessment
- Engineering substantiation

# Design - example

- A facility contains self-heating radioactive liquor stored in tanks
  - need cooling coils, with cooling water passed through
- Need to decide how many coils are required
  - choose 4, based on worst case inventory
- In operation, they find that the tank is over-cooled
  - so operators 'mothball' 2 coils
- But a coil can leak, so now radioactive liquor can fill the coil
  - 'Unmothballing' is potentially hazardous

# Fault progression - example

- Self-heating radioactive solid material in packages
  - cooled by ventilation
- What if the ventilation fails?
  - ask a specialist, who says that he cannot prove that over-heating won't occur
- Analysis assumes that over-heating occurs
  - but risk is high, and improvements are required
- Re-examine specialist analysis
  - minimal effort last time, need more time

# Consequence assessment - example

- One licensee routinely produces 2 sets of consequences
  - 'worst case' for Design Basis Analysis (DBA)
  - 'best estimate' for probabilistic safety analysis (PSA)
- For internal dose assessments, there was a factor of 200 between 'worst case' and 'best estimate'
- On deeper analysis, it was found that the 'best estimate' itself contained many conservatisms
  - this value was considered after review to be conservative enough for DBA
  - so the previous consequences were 200 times too high!

# Engineering substantiation - example

- Old building with an 'operating roof'
  - ventilated by a system drawing air from many buildings
- Over-depression in the building was identified as a fault
  - safety function of structural stability was not substantiated
- Yet no restriction was placed on the number of people who could work on the roof
  - indicates no real concern?
- Known leak paths in building fabric
  - so over-depression would not be large

# Conservatism in PSA

- Probabilistic safety assessment (PSA), unlike DBA, is intended to be 'best-estimate'
- But the 'conservative thinking' often affects (infects?) PSA too, for example:
  - worker risk estimates often assume 100% occupancy, even if it's <1%
  - an instrument that's of Safety Integrity Level (SIL) 4 may be treated as SIL 2 in a nuclear PSA. Why?

# Themes (1)

- Management of uncertainty is a key part of safety analysis
- Conservatism is an important part of safety cases
  - need overall conservatism for DBA
  - it is not necessary for every element to be conservative
- Over-conservatism, as well as under-conservatism, can be the enemy of safety
- Focus particularly on fault progression, consequence assessment and engineering substantiation
  - in addition the overall balance is very important

# Themes (2)

- The effect of combining individual conservatisms is not just cumulative; it can be multiplicative, resulting in major over-estimates in assessed results
  - Combining conservative values of multiple input values (e.g. inventory) can easily lead to a ridiculously unrealistic output value (e.g. dose), *without the knowledge of the analyst*

# Techniques for removing or managing under/over conservatism

- Techniques include:
  - explicit identification of optimisms and conservatisms within safety case documents;
  - author self-checking of documents;
  - good communication, and avoiding 'silo working';
  - awareness of the multiplicative effect of over-conservatisms;
  - use of sensitivity analysis;
  - appropriate use of expert judgement; and
  - appropriate challenge of assumptions and conclusions (asking 'Does it look right?'), within a team-working environment

# Conclusions

- Appropriate conservatism
  - is key to achieving an appropriate safety case
  - is often very difficult to achieve
  - needs an excellent technical understanding of the whole analysis, including specialist contributions
  - requires excellent communication skills
- More detail is available in the SCF Guide, on the Safety Case Forum page of the Nuclear Institute website: [Safety Case Forum](#)
- Further info: [alec.bounds@arcadis-uk.com](mailto:alec.bounds@arcadis-uk.com)