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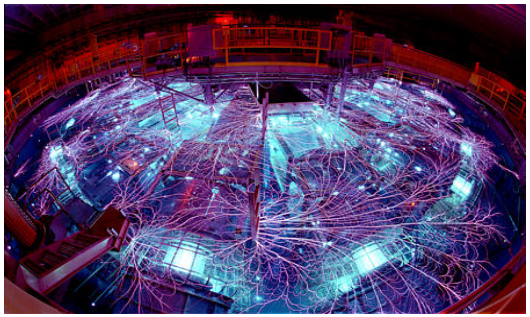
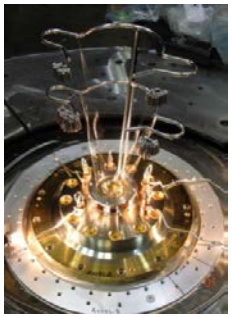
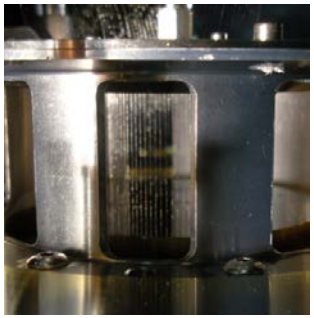
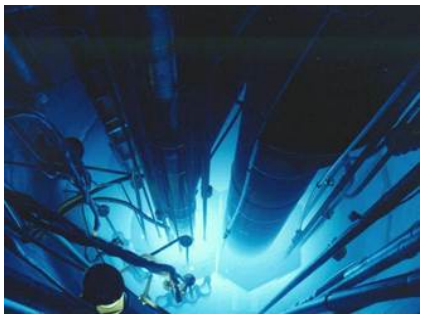
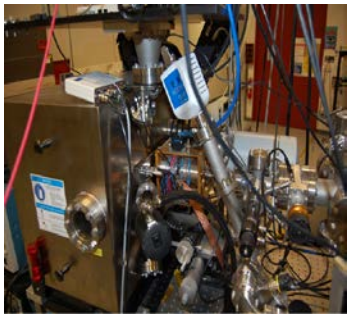

"Dosimetry User's Perspective on Covariance Data"

Presented at: CSEWG 2018, November 08, 2018

Patrick J. Griffin
Senior Scientist
Org. 1300, Radiation and Electrical Sciences

Date: November 06 – 09, 2018

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Outline of Presentation

- **Fundamental Axiom for Dosimetry**
- **Historical Perspectives**
- **Comments on ENDF/B-VIII.0(beta5) covariance data**
- **Role for calculated cross sections**
- **Status of ASTM standard that address dosimetry cross sections**

FUNDAMENTAL AXIOMS FOR DOSIMETRY:

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- To be considered “information/data”, the information needs to have an associated uncertainty statement.
- The uncertainty statement needs to be based on the derivation of the information.

Development of covariance matrices needs to be an integral part of the nuclear data evaluation process!

Historical Perspective #1

- **Early JENDL Dosimetry Cross Sections:**
  - **In 1991 the Dosimetry Integral Test Working Group of the Japanese Nuclear Data Committee compiled and released the first JENDL Dosimetry library (JENDL/D-91). It applied the IRDF-85 covariance matrices to the existing JENDL-3 cross sections. Although called "dosimetry" library, this library was rejected by the dosimetry community because the covariance data bore no relationship to the selected cross section.**
  - **The Working Group re-evaluated the dosimetry cross sections and associated covariances, resulting in the JENDL Dosimetry File 99 (JENDL/D-99). This library was accepted by the dosimetry committee.**
  - **Ref:*www.iaea.org/inis/collection/NCLCollectionStore/_Public/31/049/31049718.pdf***
  - **Ref*: https://www.osti.gov/scitech/servlets/purl/10183494-o18qP7***

Historical Perspective #2

- **At the 2008 summer CSEWG-sponsored Workshop on Neutron Cross Sections Covariances in Port Jefferson, P.J. Griffin's presentation contained the slides found on the following two pages.**
  - **Workshop on Neutron Cross Section Covariances June 24-28, 2008, Port Jefferson, New York, USA**
  - **Papers in Nuclear Data Sheets, Vol. 109, Issue 12, pages 2725-2922, December 2008.**

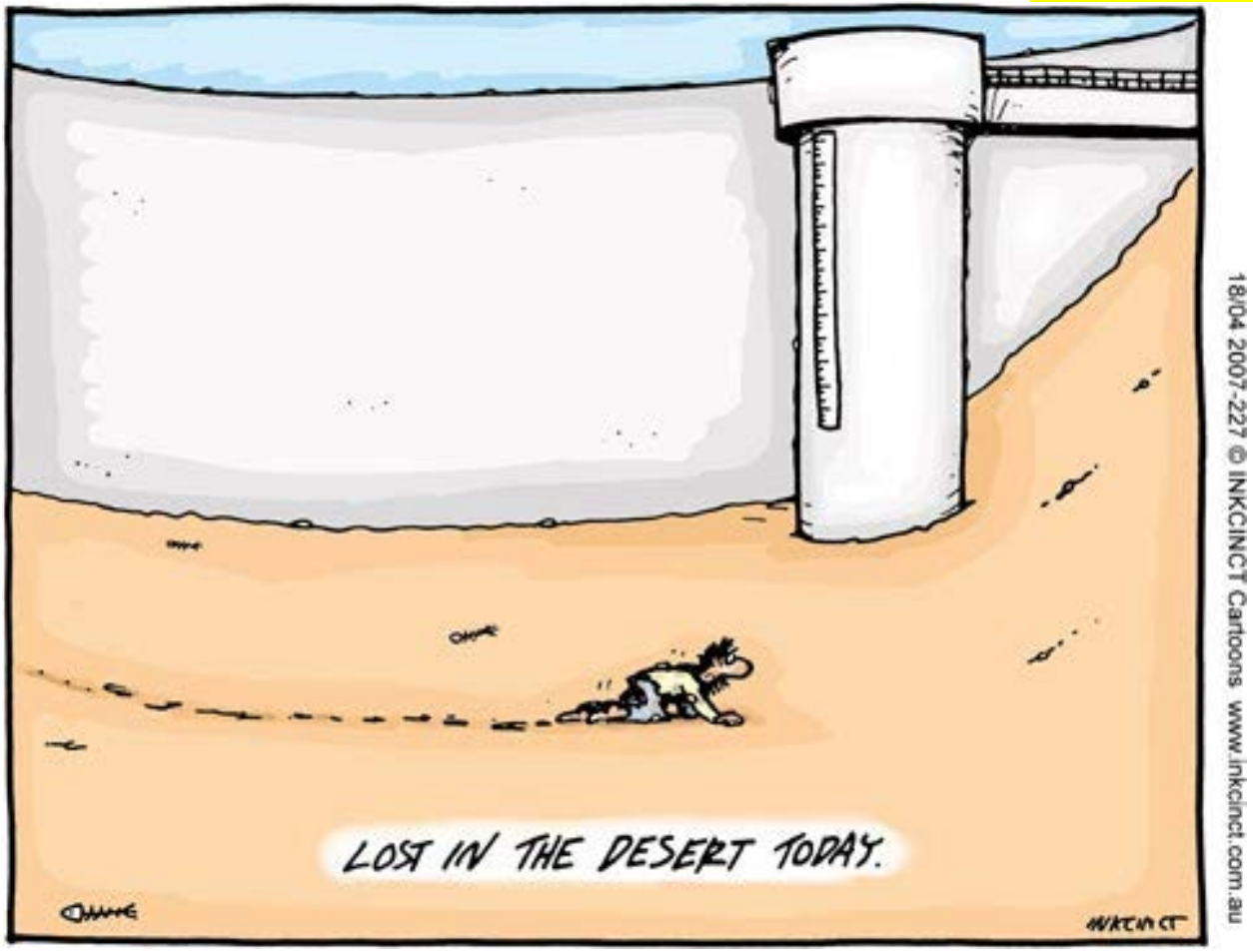
Historical Perspective #3

- **Due to the lack of experimental data and, in light of the need, the latest IRDFF "dosimetry" library "adopted" the TENDL-2015 cross sections for energies above 20 MeV. It merged this data onto their lower energy evaluations and renormalized TENDL data to prevent a discontinuity at 20 MeV.**

- **ASTM E1018 standard for dosimetry cross sections used in reactor safety analysis has rejected use of the IRDFF cross sections for energies above 20 MeV due to:**
  - **lack of experimental validation above 20 MeV**
  - **lack of treatment of the uncertainty near the transition energy to address the "renormalization".**

Why has ENDF/B-VII abandon us? Walled us out?

VG extracted from CW2008 presentation



Role for Low Fidelity Covariance Data

VG extracted from CW2008 presentation

- **Low fidelity effort focuses on use of parametric variation in nuclear physics models, e.g. EMPIRE**
  - **Calculation-only approach not sufficient for dosimetry purposes**
  - **Experimental data must play a role**
  - **Covariance we use must be related to the cross section used – not appended to a different evaluation that had different development roles – ASTM E1018**
  - **Uncertainty in physics models – not just parametric variation – needs to be incorporated**
    - **E.g. Issue with Watt fission spectrum in LEPRICON methodology**

CURRENT STATUS: UNCHANGED

- We appear to be at the same place now for ENDF/B-VIII.0 cross sections.
- And it is a decade later.

Does the Dosimetry Community Need Covariance Data?

- The answer is a strong YES

- This was addressed in the 2008 CSEWG Port Jefferson Workshop and was answered back in the 1980's.
  - See:http://www.sciencedirect.com/science/article/pii/S0090375208000902

- "The REAL-80/84 exercises demonstrated [17] that the dosimetry cross section covariance matrices play the dominate role, as opposed to the *a priori* spectrum covariance matrix, in refining the uncertainty in the adjusted spectrum."
  - [17] H.J. Nolthenius, E.M. Zsolnay, W.L. Zijp, E. J. Szondi, "Nuclear Data Aspects Encountered in the REAL80 and REAL84 Intercomparisons", report NDS-0179, Proceedings of an IAEA Consultants' Meeting on Nuclear Data for Radiation Damage Estimates for Reactor Structural Materials, held in Santa Fe, New Mexico, USA, 20-22 May 1965, International Atomic Energy Agency, Nuclear Data Section, Vienna, Austria, pp. 95-105, 1985. Available at: http://www-nds.iaea.or.at/reports-new/indcreports/ indc-nds/indc-nds-0179.pdf#page=98.

WHAT DO WE CURRENTLY RECOMMEND?

- **The dosimetry community now looks to the IAEA/NDS to recommend dosimetry cross sections.**
- **The best current dosimetry library is IRDFF v1.05:**

https://www-nds.iaea.org/IRDFF/

Are We Satisfied with This Status?

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- **No!**

- **When doing radiation transport calculations, analysts must continually be reminded to tally with the IRDFF and not the transport material cross sections.**
- **We would like the transport cross sections, typically derived from the ENDF/B nuclear data, to be consistent with the best dosimetry cross sections.**

Is there a role for calculated cross sections?

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- **Yes!**

- **TENDL-2015 is an excellent example of how calculated cross sections have been used by the dosimetry community.**
  - **Its random libraries are critical to the non-linear propagation of uncertainties in more complex response functions, e.g. silicon damage metrics.**
- **Cross section calculations have traditionally played an important role in ALL nuclear data evaluations.**
- **The key is how to integrate the calculated cross sections with available experimental measurements.**

What do the standards/regulatory communities say?

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- **The U.S. Nuclear Regulatory Agency (NRC) references the ASTM standards, but allows nuclear utilities to establish their own evidence for compliance with the NRC-mandated safety margins.**
  - **e.g. surveillance dosimetry used to determine the safety margin in the belt-line weld of PWRs.**

ASTM Standards

- **E1018: Standard Guide for Application of ASTM Evaluated Cross Section Data File, Matrix**
- Section 4.4: The ASTM-recommended cross sections and uncertainties are based mostly on the ENDF/B-VI and IRDF-2002 dosimetry files – not ENDF/B-VII.
  - Current revision (in draft) references IRDFF-1.05
- Section 6.1: All cross section data in the ASTM file, except damage functions which are given for the purpose of standardization and cover cross sections, must have uncertainties specified. Since these data tend to be highly correlated, to be meaningful, the uncertainty shall include correlations. Therefore, the uncertainties must be specified in the form of a covariance matrix.
- Section 6.2: The uncertainty matrix must be associated directly with the cross section file

What Do I See in ENDF/B-VIII.0(beta) (1/2)

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- **I see a mixed situation:**
  - **^{28}Si (MAT=1425) – good**
    - **well documented uncertainties**
    - **covariance matrices integral with the cross sections**
    - **Uncertainties "based on data and estimates of uncertainties associated with the model calculations."**
      - **Use of TNG code, but considers spread in experimental data**
      - **Appropriate use of subject-matter expertise**

- **D.M. Hetrick, D.C. Larson, and C.Y. Fu, "Generation of covariance files for the isotopes of Cr, Fe, Ni, Cu,and Pb in ENDF/B-VI," Oak Ridge National Laboratory report ORNL/TM-11763 [ENDF-350] (1991).**
- **D.M. Hetrick, D.C. Larson, C.Y. Fu, S.J. Epperson, "Evaluation of the ^{28,29,30}Si Isotopes for ENDF/B-VI," Oak Ridge National Laboratory, report ORNL/TM-11825, April 1997.**

What Do I See in ENDF/B-VIII.0(beta) (2/2)

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- **I see a mixed situation:**
  - **^{58}Ni(n,p) (MAT=2825) – not clear**
  - **From comments:**
    - **File 3 data calculated with CoH3 code and adjusted to data at 3, 6, and 12 MeV**
      - **Elsewhere under ENDF/B-VI embedded comments I still read cross sections from up to 6 MeV from GLUCS simultaneous evaluation with data driven evaluation from 6 – 13 MeV, > 13 MeV TNG calculations. This is probably not applicable and are stated to be comments "preserved for record keeping purposes".**
    - **Covariances from Aug-2011 COMMARA-2.0.**
      - **No clear tie in with the methodology used for the cross section evaluation, i.e. no consideration of spread in experimental data or adjustment to experimental data and COMMARA uses the EMPIRE/KALMAN methodology - a different code with different models and associated sensitivities.**
  - **Both the ENDF/B-VIII.0(beta) ^{58}Ni(n,p) cross section and covariance data appears reasonable – they are just not derived in an integral manner**

Calculated Cross Sections and Covariances Will Differ with the Code/Method Used

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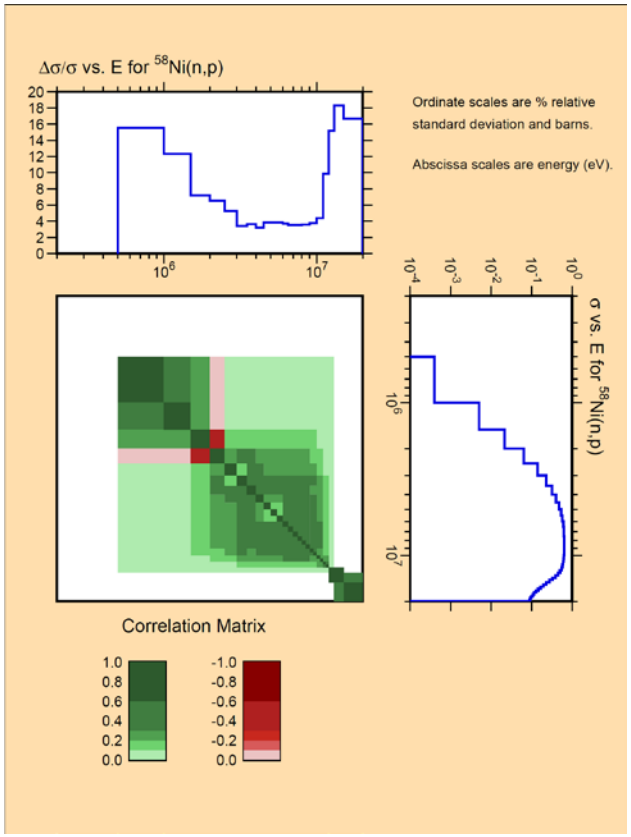
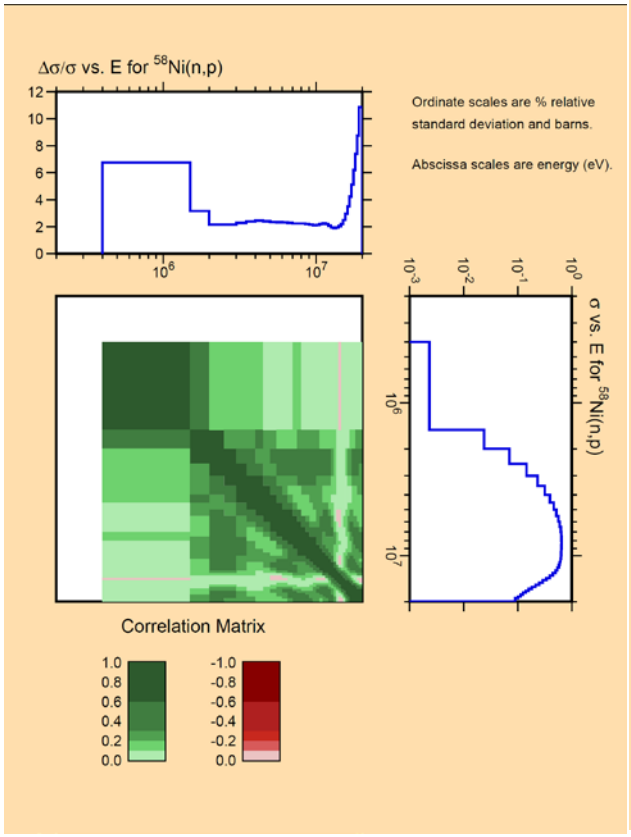
^{58}Ni(n,p) Reaction

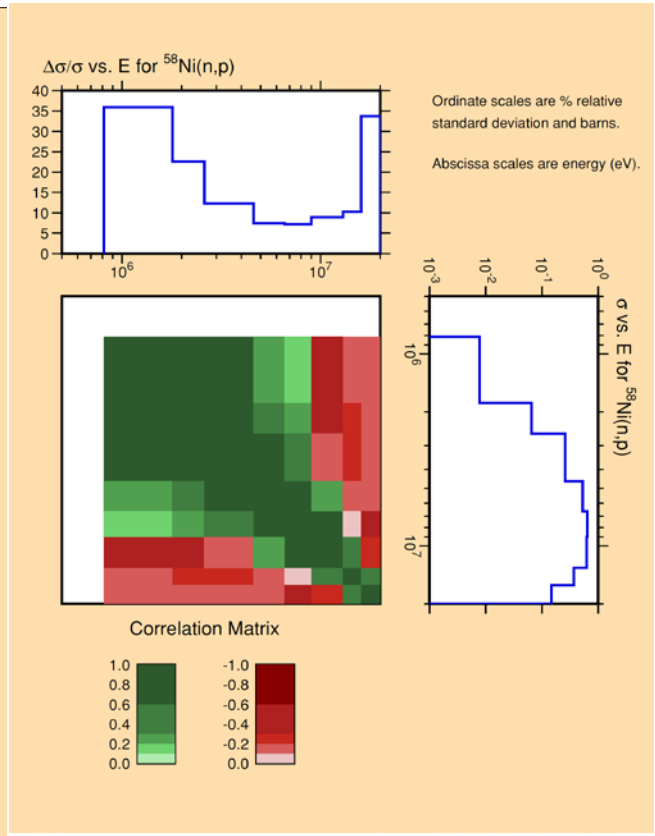
ENDF/B-VIII.0 (beta)



IRDFF-1.05

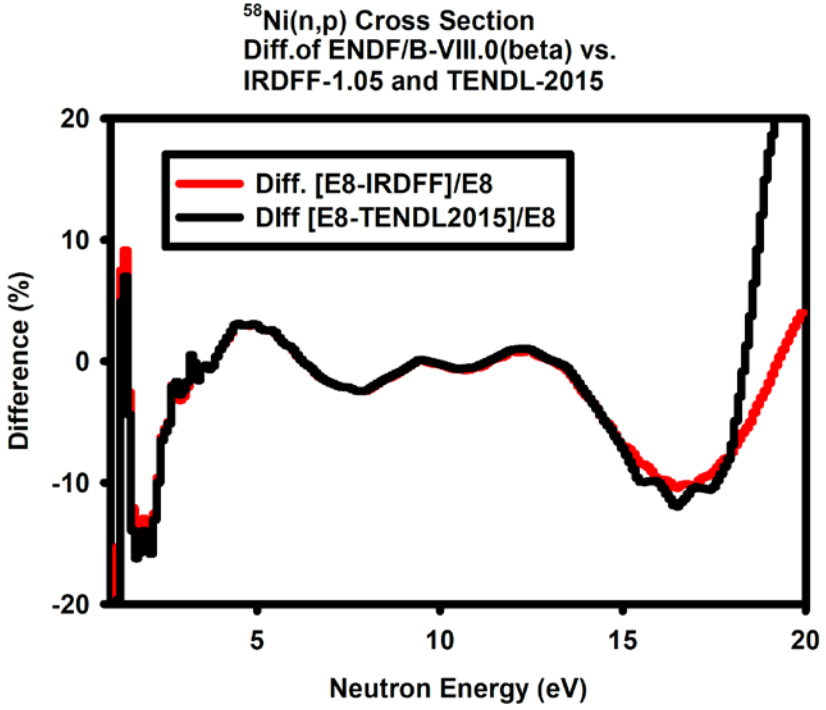


TENDL-2015

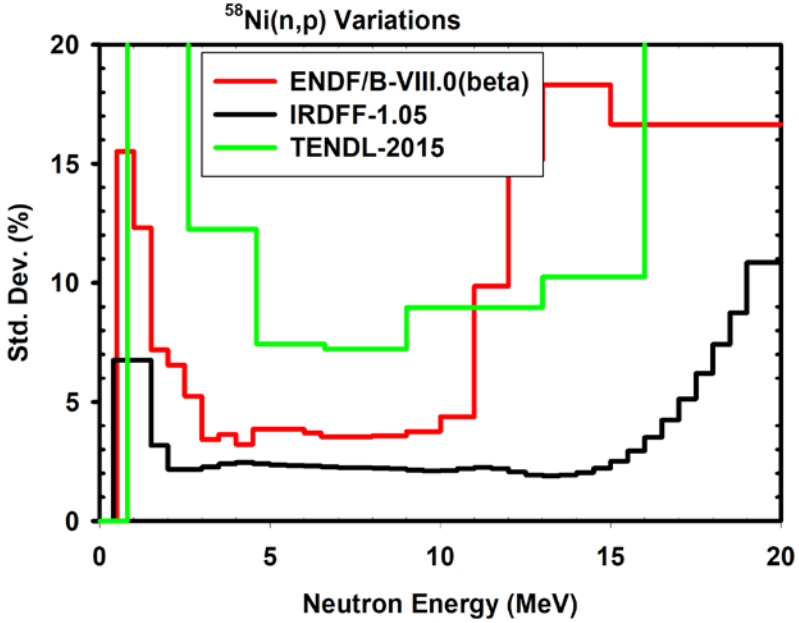


Comparison of Variation in ^{58}Ni(n,p) Cross Section and Reported Uncertainty

Diff. between ENDF/B-VIII.0(beta) and IRDFF-1.05 and TENDL-2015



ENDF/B-VIII.0(beta), IRDFF-1.05 and TENDL-2015 reported standard deviations



Note, TENDL-2015 over-rode the baseline cross sections with the IRDF-2002, but retained their covariances derived by model parameter variations.

Conclusions – from a dosimetry perspective

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- **For dosimetry applications, the quantity and the associated uncertainty need to be consistent**

- **We can accept any number of approaches from fully data-driven to fully-calculated, but we:**
  - **desire some consideration of "model defect" in calculated uncertainties**
  - **desire consideration of available experimental data in validating uncertainties**
  - **can accept the inclusion of some subjectivity by the evaluator – as long as it reflects considered thought and not merely an automated processing**

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Questions