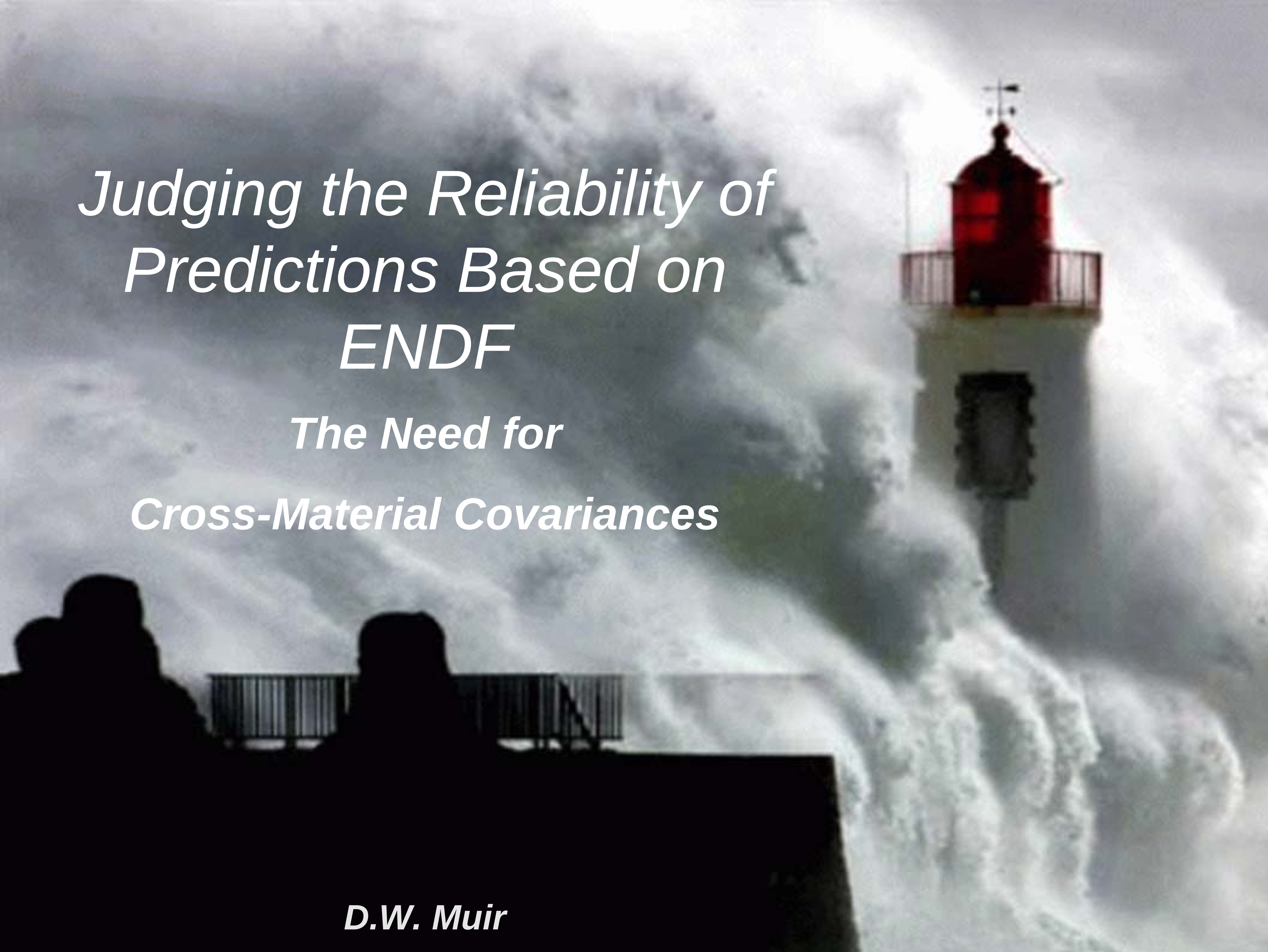

Judging the Reliability of Predictions Based on ENDF

The Need for

Cross-Material Covariances

D.W. Muir

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What Users Need

The end users of evaluated nuclear data need covariance information that adequately describes the uncertainty of the data. But what constitutes an "adequate" description? To answer this, we need to consider the question of how the information will be used. We list below what appear to be the four main uses of data covariances.

Data Assessment ... Estimating the accuracy of predictions of applied quantities (such as critical mass, shield thickness, or tritium breeding ratio) due to the uncertainties of the basic data. This is also called the "forward propagation of uncertainties."

This is the **most important** single use of the ENDF covariance files. Supplying users with poorly characterized covariances runs the risk that future reactors, accelerators and other devices **won't work as designed** or will be burdened with unnecessarily high design margins and, hence, **unnecessarily high costs**.

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Additional Major Applications

The following uses are all important, but, in these applications, the role of the data and their covariances is somewhat secondary, serving mainly as a vehicle for transferring information from measurements of a quantity that is relatively easy to measure to a quantity that is difficult to measure.

Data Adjustment ... Improving the accuracy of design calculations by exploiting the information content of relevant integral experiments.

Reactor Dosimetry ... Using thin-foil activation measurements to infer neutron fluence and spectra, especially within a reactor pressure vessel.

Remote Sensing ... Using various nuclear measurements to infer the composition of an inaccessible material sample, such as in oil-well logging.

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An evaluated data file, such as ENDF, that includes specifications of data covariances needs to provide both uncertainty and correlation information in sufficient detail to meet the need of intended applications.

Need for energy-energy correlations

A common feature of these four "front-line" applications is that they involve neutron transport in bulk media, so neutron slowing down and transport is important. This means, in turn, that sums over energy are important, so **energy-to-energy correlations** in the data should be evaluated and provided to the user.

Need for material-material correlations

Another common feature of these primary applications is they involve transport in a mixture of materials, both isotopic mixtures and mixtures of elements. This means that sums over materials are equally important, so material-to-material correlations in the data should also be evaluated and provided to the user.

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It is helpful to examine the sources of cross-material correlations. The following two sources are noteworthy.

Shared use of standards

Probably the most important source of material-material correlations is the shared use of nuclear measurement standards. Suppose that the cross sections for ^{232}Th(n,f) and ^{238}U(n,f) are both evaluated as ratios to ^{235}U(n,f). In this case, the magnitude of the uncertainty of the ^{235}U(n,f) cross section will affect the magnitudes of the uncertainties of the two derived cross sections. Since this single source of uncertainty is common to the two materials, this will also introduce important correlations between these two cross sections.

Measurements performed on elemental targets

High-accuracy measurements of the total cross section are often performed using the transmission technique with fairly massive, elemental targets. The isotopic totals must sum to the accurately measured elemental total, so this will introduce large negative

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In at least one important area, data covariances are also needed in the internal work of the data evaluation community, namely,

Nuclear Data Standards ... All CSEWG evaluators rely on the validity of the covariances of the measurement standards.

Modern evaluations of the nuclear data standards, such as that recently completed for ENDF/B-VII, are performed using simultaneous evaluation methods. These methods recognize the valuable information that is contained in the large body of available **ratio measurements.** A simultaneous evaluation introduces these ratio data in a statistically correct way.

A key outcome of such a simultaneous evaluation is reduced uncertainties (relative to what would be obtained without employing ratio data). However, this reduction of uncertainty is accompanied by the introduction of significant **cross-material covariances** between the different standards reactions. A consistent presentation of the

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Some Suggestions for Solutions

A major challenge before the covariance committee will be to devise practical solutions that **(a) preserve the validity of the files for uncertainty propagation in bulk media and (b) allow proper handling** of the covariances of the measurement standards. Both of these require **including cross-material covariances** in the file.

This need for cross-material covariances is an "inconvenient truth", especially in light of the recent trend toward **more isotopic evaluations** of neutron interaction data and a general enlargement of the neutronic data files in order to **improve the physics** (e.g., angle-energy correlation).

While the CSEWG and data-user communities may be willing to accept, let's say, a ten-fold increase in the size of certain of the data files, they are not going to accept with a 100-fold increase in the size of the corresponding covariance files. Thus there is an inherent tension between the two goals of completeness and compactness.

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The Appealing Goal of Simplicity

It is appealing to think that we can eliminate some of the complexity of the ENDF-6 covariance formats, to achieve such goals as (a) improved human readability of the covariance files and (b) covariance formats that are easier to document and process.

It's Not a Bug ... It's a Feature

In this regard, it is important to note that most of the apparent complexity of the covariance formats is the direct result of past efforts to keep the size of the files manageable. A good example is the uranium-thorium example introduced above. The current ENDF-6 format would allow the evaluators include the contribution of ^{235}U(n,f) covariances to the ^{232}Th(n,f) and ^{238}U(n,f) covariances simply by cross-referencing the standard. This is true of both the within-material covariances and the cross-material covariances. One could, indeed, simplify the ENDF format by eliminating this feature, but then one would have to repeat the ^{235}U(n,f) covariance data explicitly in many

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For the reasons we have discussed, file size concerns are likely to increase in the future. It seems likely, therefore, that we will need to go in the direction of even more sophisticated formats.

File Management Issues

In the past, we have treated the covariance files for a given material as just a higher MF number, to be managed in the same way as other MF numbers are. This approach has many advantages, but we may be approaching the day when it cannot be sustained. Below we discuss two proposals that attempt to "think outside the box" to address the inherent conflict between the need for covariance files that are complete, and at the same time, compact.

Suggestion for Elemental Covariance Evaluations. One change in the data structures that would help specifically with the isotopic evaluation situation could be to allow an evaluator to associate a covariance evaluation (MF 30 and above), not with a single MAT

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This suggestion would be in the same spirit as the existing format that allows the evaluator, using MT=851-870, to define specific combinations of partial reactions as single reactions for covariance-specification purposes (the "lumped partial" format).

This would be very effective in compressing the covariance file in the medium-mass region, but it would not be as helpful for light or for heavy isotopes, where covariances are needed mainly for individual isotopes.

Potential for Physical Separation of the Files

A more fundamental change in data structures would be to move all ENDF covariance information into a file that is physically separate from the corresponding general purpose data files. This would permit the use of covariance files that are much larger than would otherwise be possible.

If the community should, at some point, opt for this kind of "partitioning," summary information from such a large external covariance file would presumably be included as comments in the


Thank you ...
Any questions?