STEPS TO GENERATE MODEL-ASSISTED POD
FMA APPROACH
Draft of 6/02/05

Definitions:

Controlling Factor: A factor that controls the results of an NDE measurement. Examples include part geometry; material microstructure; flaw location, size and morphology; measurement system; inspection plan; physical sources of noise, and human factors.

Physics-Based Model: A solution to a physics problem, defined by a set of governing equations with a subset of controlling factors as independent variables, which predicts the result of an NDE measurement of flaw response and/or noise.

Input Parameters: Specific values of controlling factors that define the values of the independent variables appropriate to a particular inspection problem whose POD is to be assessed with the assistance of a *physics-based model*.

Input Parameter Distributions: A distribution of *input parameters*, determined in the context of a particular inspection situation. When provided as an input to a *flaw signal simulation tool*, a *flaw signal distribution simulation* will result

Simulation Tool: A computer code, based on a numerical implementation of a *physics-based model* that can make a prediction of a measurement response when provided with a set of *input parameters*.

Flaw Signal Simulation: A deterministic prediction of the signal produced by a flaw using a *simulation tool* with a particular set of *input parameters*.
Flaw Signal Distribution Simulation: A prediction of the distribution of signals produced by a flaw. Variations in the signal might be produced by an *input parameter distribution* or by the specification of a parameter related to the rms noise and a model that predicts how the distribution of noise signal that can add either constructively or destructively to the flaw signal will produce a distribution of signals from that flaw.

Noise Distribution Simulation: A prediction of the distribution of noise in a given physical situation.

Marginals: The average and variance of a stochastic variable.

Protocol:

1. Identify the scope of the POD study in the context of the intended purpose.
   a. Determine whether one is seeking an absolute POD determination (prediction of reality) for lifing purposes or a relative determination for the purposes of qualifying a replacement inspection technique.
   b. Specify the degree of accuracy desired. The scale of the activity should be adjusted to fit the purpose.
   c. Specify a measure that will indicate when the study will be considered to be complete.

2. Identify those factors that control the signal and noise in the experiment (*Controlling Factors*).

3. Determine whether a *physics-based model* can be used to predict the influence of each controlling factor on flaw signal and noise. For those *controlling factors* for which the answer is yes, go to step 4 and its sequels to treat those aspects of the POD study that can be analyzed by physics-based models. Otherwise, go to step 7 and its sequels to treat those aspects of the problem that should be treated empirically.

4. Acquire *simulation tools* for signal and noise for the factors whose effects can be predicted by a *physics-based model*.
   a. Identify needed *simulation tools*, including the range of *input parameters* for which they will be expected to be used.
   b. Determine if validated *simulation tools* exist. If the answer is yes, acquire the tools and go to step 5. Otherwise,
   c. Develop new *simulation tools*.
      i. Develop appropriate *physics-based models*
      ii. Develop computer software that makes numerical predictions based on those models.
      iii. Incorporate these tools in *simulation tools* that include appropriate user interfaces.
   d. Validate the accuracy of the *simulation tools* in the laboratory through well controlled experiments
      i. Establish the scope of the intended validation, including the range of parameter values to be considered and the level of agreement between experimental measurements and the predicted results that will be considered to be satisfactory
      ii. Include a careful analysis of uncertainties, including consideration of uncertainties in the experimental measurements, uncertainties in the values *of input parameters* to the model, and sensitivity of model predictions to the latter

i. Document the results of the validation experiments in a way that will allow them to be considered in step 4.b of other studies.

5. Acquire input parameters and/or *parameter distributions* appropriate to the measurement situation of interest
   a. Determine whether the *input parameters/parameter distributions* are known. If the answer is yes, go to step 6. If the answer is no,
   b. Determine the *input parameters/parameter distributions* from experiment or expert opinion.
6. Conduct *Flaw Signal Distribution Simulations* and *Noise Distribution Simulations*
   a. Use *simulation tools* to predict mean response and those components of variability of signal and noise described by the *physics-based models*. This defines the marginals associated with each factor whose effects can be treated in terms of *physics-based models*.
   b. Go to step 10.
7. Acquire information about effects of controlling factors that must be treated empirically.
   a. Identify *controlling factors* to be considered, including the range of conditions appropriate to the particular inspection of interest.

b. Determine if the sources of variability controlled by factors that must be treated empirically are statistically independent so that variances add. If the answer is yes, go to step 8 and its sequels. If the answer is no, assess whether independence would be a conservative assumption and if that assumption would lead to acceptable conclusions. If that would be the case, then assume the independence and proceed to step 8. Otherwise, go to step 9 and its sequels. Note that it is often hard to determine independence rigorously. Physical arguments, previous experience, or expert opinion should be used wherever possible to classify sources of variability.

8. Acquire marginal information for independent factors.
   a. Determine if empirical studies for these set of conditions have been previously conducted in a way that defines the needed marginals. If the answer is yes, acquire the marginal information and go to step 10 and its sequels. Otherwise,
   b. Design experiments to assess marginals associated with each controlling factor whose effects are to be treated empirically and have been determined to be independent of those of other controlling factors.
   c. Conduct the needed experiments
   d. Extract the needed marginals.
   e. Go to step 10

9. Acquire covariance information for dependent factors.
    a. Determine if acceptable bounds on the correlation coefficient can be established based on physical arguments, previous experience, or expert opinion. If yes, establish those bounds and proceed to step 9.d. Otherwise,
    b. Design experiments to determine the correlation matrix or other parameters needed to jointly describe multiple sources of variability and thus fully define the noise statistics.
    c. Conduct the needed experiments.
    d. Develop the full covariance description for the dependent factors.
    e. Go to step 10
10. Combine results of steps 6, 8 and 9 into a full description of the distributions of signal and noise
    a. If sources of variability are statistically independent, compute total variance as the sum of the variances derived from models and empirical measurements.
    b. If sources of variability are not statistically independent, compute the generalization of the above
11. Compute POD, PFA, ROC