ASSESSMENT OF A BAYESIAN MODEL AND TEST VALIDATION METHOD

Yogita Pai, Michael Kokkolaras, Greg Hulbert, Panos Papalambros, Univ. of Michigan
Michael K. Pozolo, US Army RDECOM-TARDEC
Yan Fu, Ren-Jye Yang, Saeed Barbat, Ford Motor Company

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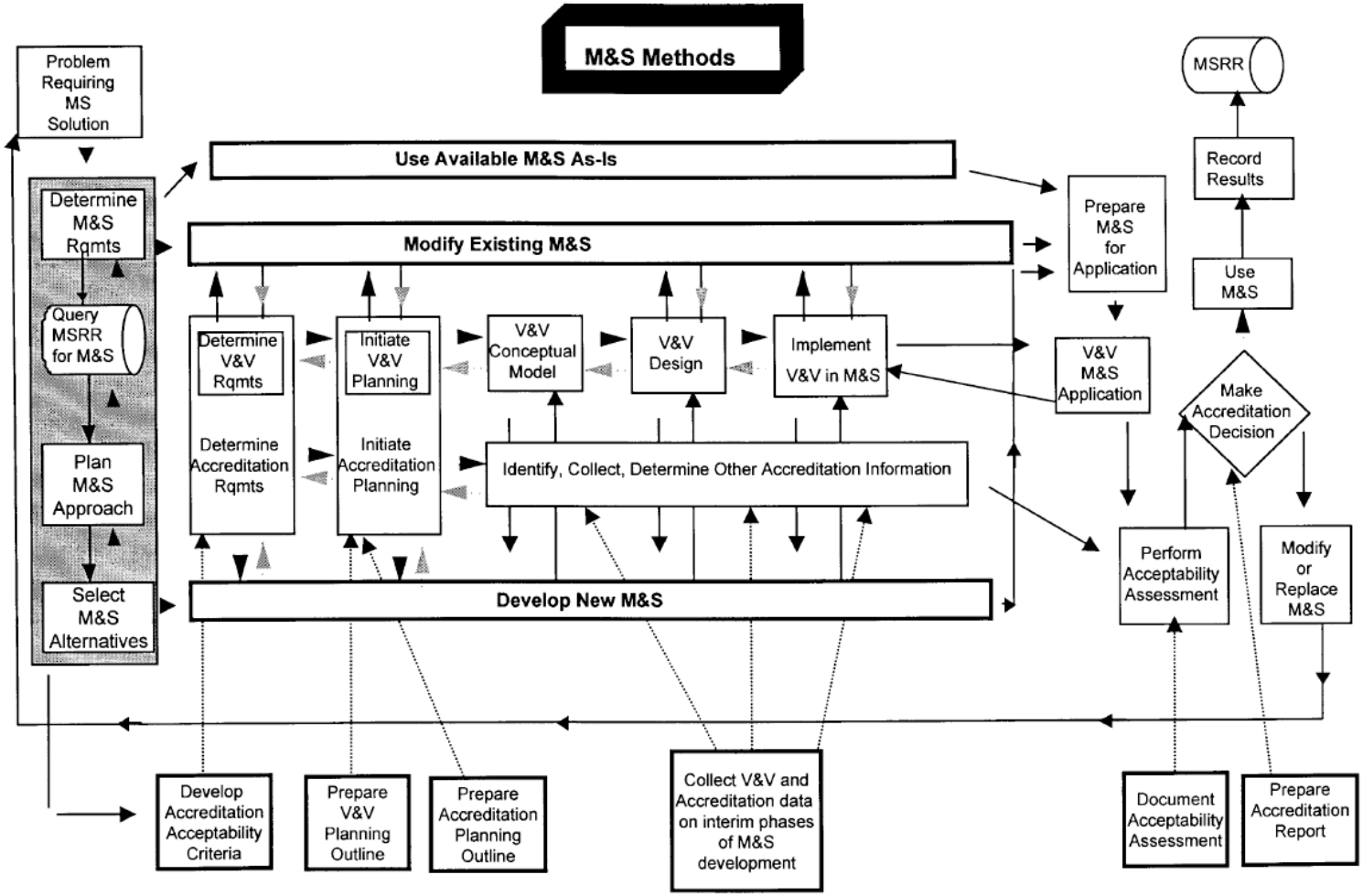
Need for Validation Methodology

MSTV
MODELING AND SIMULATION, TESTING AND VALIDATION

- Systematic method for validation necessary
  - Modeling and Simulation
  - Laboratory test
  - Validation of designs
- Reduce need for Subject Matter Experts
- Reduce number of field tests
- Assess cost of validation and certification
- Use existing data mines of tests, M&S, and designs

VV&A of Army M&S



Dept. of Army pamphlet 5-11: *VV&A of Army M&S*

Bayesian Confidence Method

- Model validation under uncertainty
  - Uncertainty in field data
  - Uncertainty in model data
  - Validation of designs
- Multiple, incompatible data channels can be evaluated
- Interval-based method provide more robust evaluation

Bayesian Confidence Method

MSTV
MODELING AND SIMULATION, TESTING AND VALIDATION

Physical test → Multivariate test data

CAE model → Multivariate CAE results

Normalization

Normalized test data

Normalized CAE results

Probabilistic Principal Component Analysis

Reduced test data

Reduced CAE results

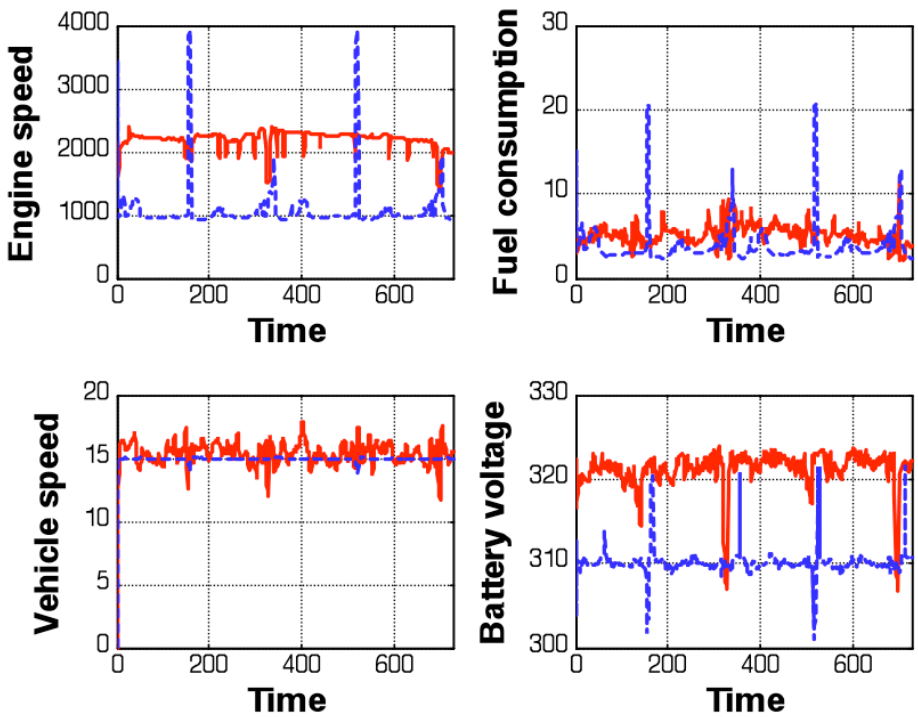
Interval-based hypothesis testing and Bayes factor (BF) calculation

BF Confidence

Jiang, Fu, Yang, Barbat, Li, Zhan, SAE 2009 World Congress

Comparison of Model and Test

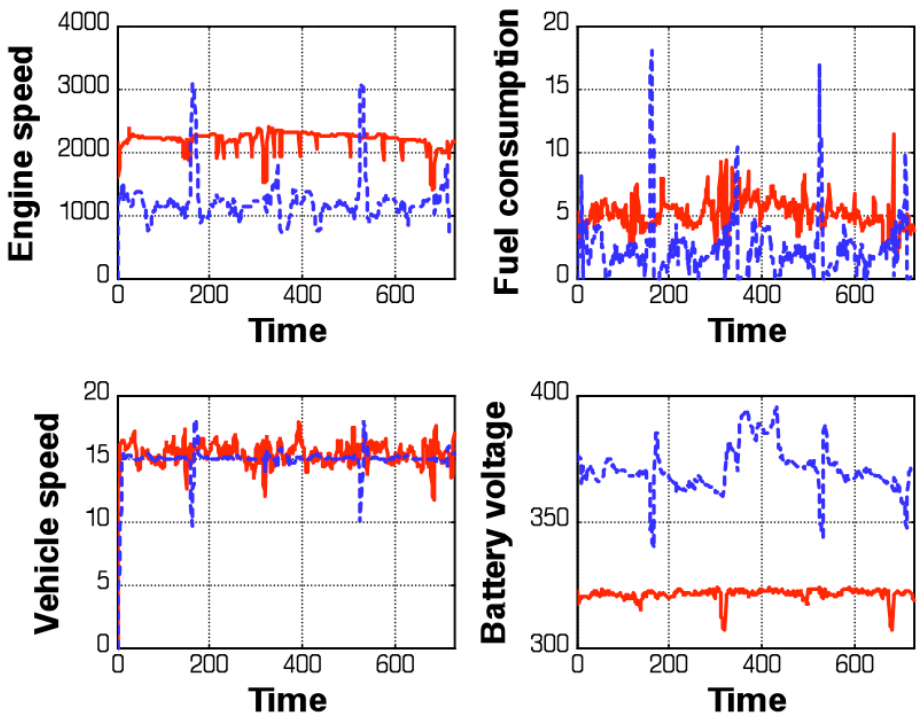
- Model 1, Course 1



Blue = model 1
Red = test

Comparison of Model and Test

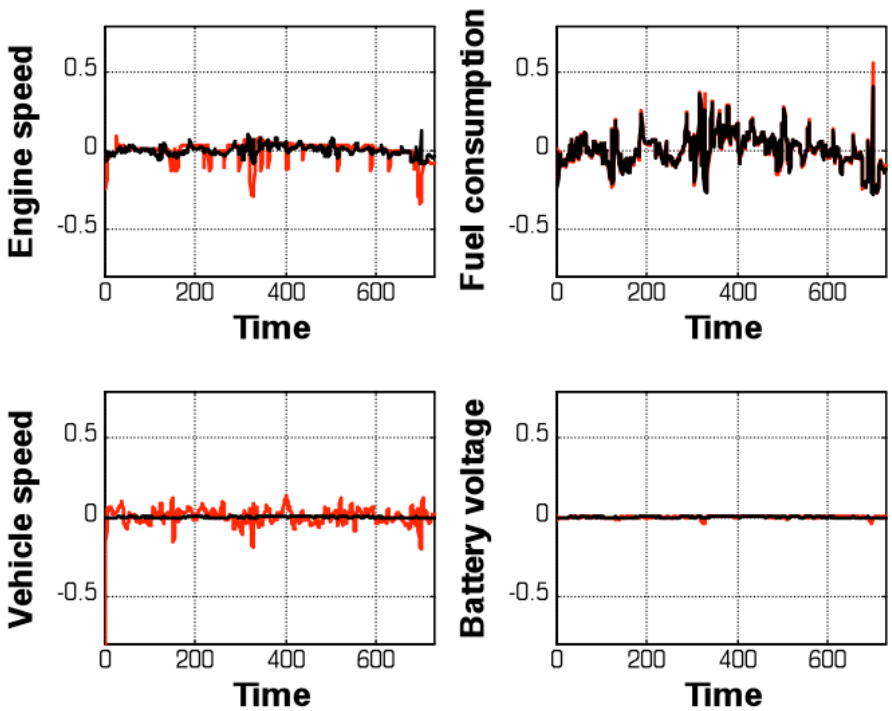
- Model 2, Course 1



Blue = model 2
Red = test

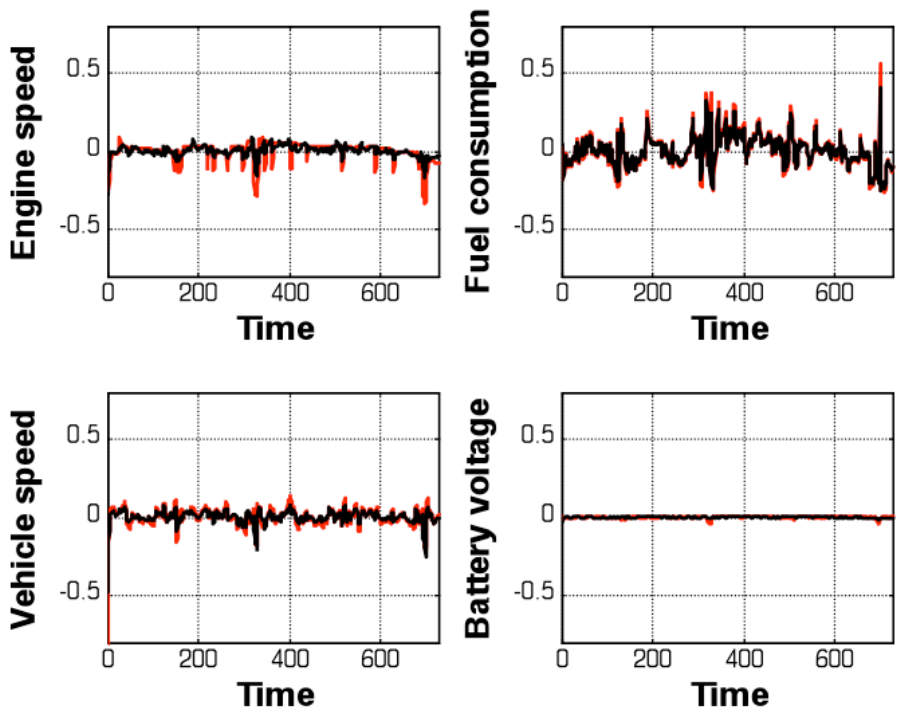
Data Reconstruction

- Course 1
- First principal component, 62% total variability captured



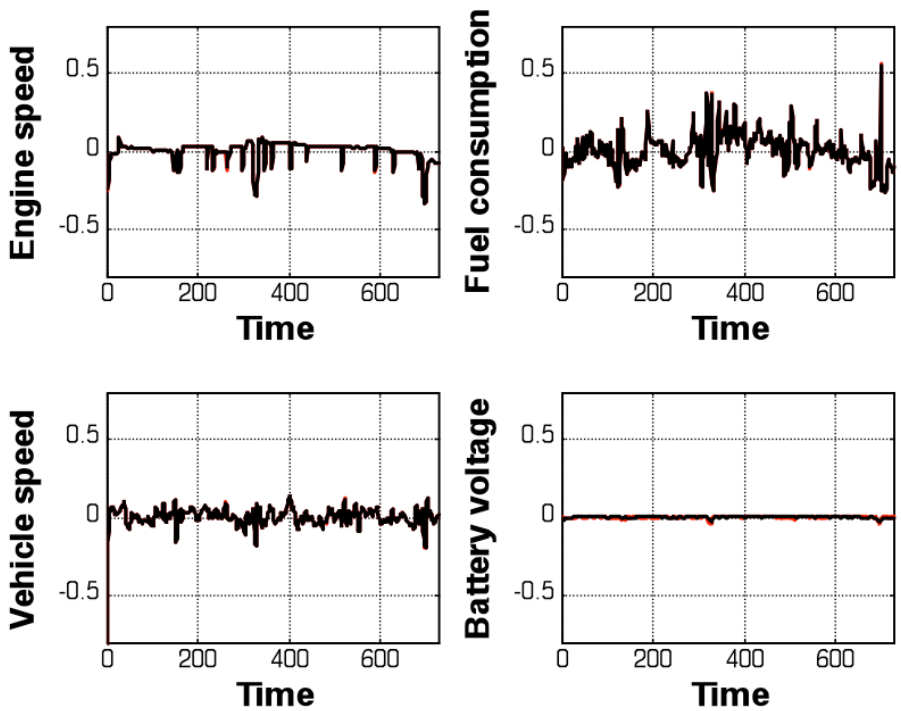
Data Reconstruction

- Course 1
- First 2 principal components, 86% total variability captured



Data Reconstruction

- Course 1
- First 3 principal components, 99.9% total variability captured



Bayesian Hypothesis Testing

Reduced test data, $\mathbf{x}_t$
with variability Σ_t

Reduced CAE results, $\mathbf{x}_c$
with variability Σ_c

Difference $\mathbf{d} = \mathbf{x}_c - \mathbf{x}_t$

➢ sample statistics: $\bar{\mathbf{d}} = mean(\mathbf{d})$ ➢

$$\Sigma = cov(\mathbf{d}) + \Sigma_t + \Sigma_c$$

∨

Multivariate hypothesis test: Assuming prior $\mathbf{d} \sim N(\boldsymbol{\mu},\Sigma)$

H_o:$|\boldsymbol{\mu}| \leq \boldsymbol{\varepsilon}$ (accept) *versus* H_a:$|\boldsymbol{\mu}| > \boldsymbol{\varepsilon}$ (reject)

∨

Bayesian factor calculation

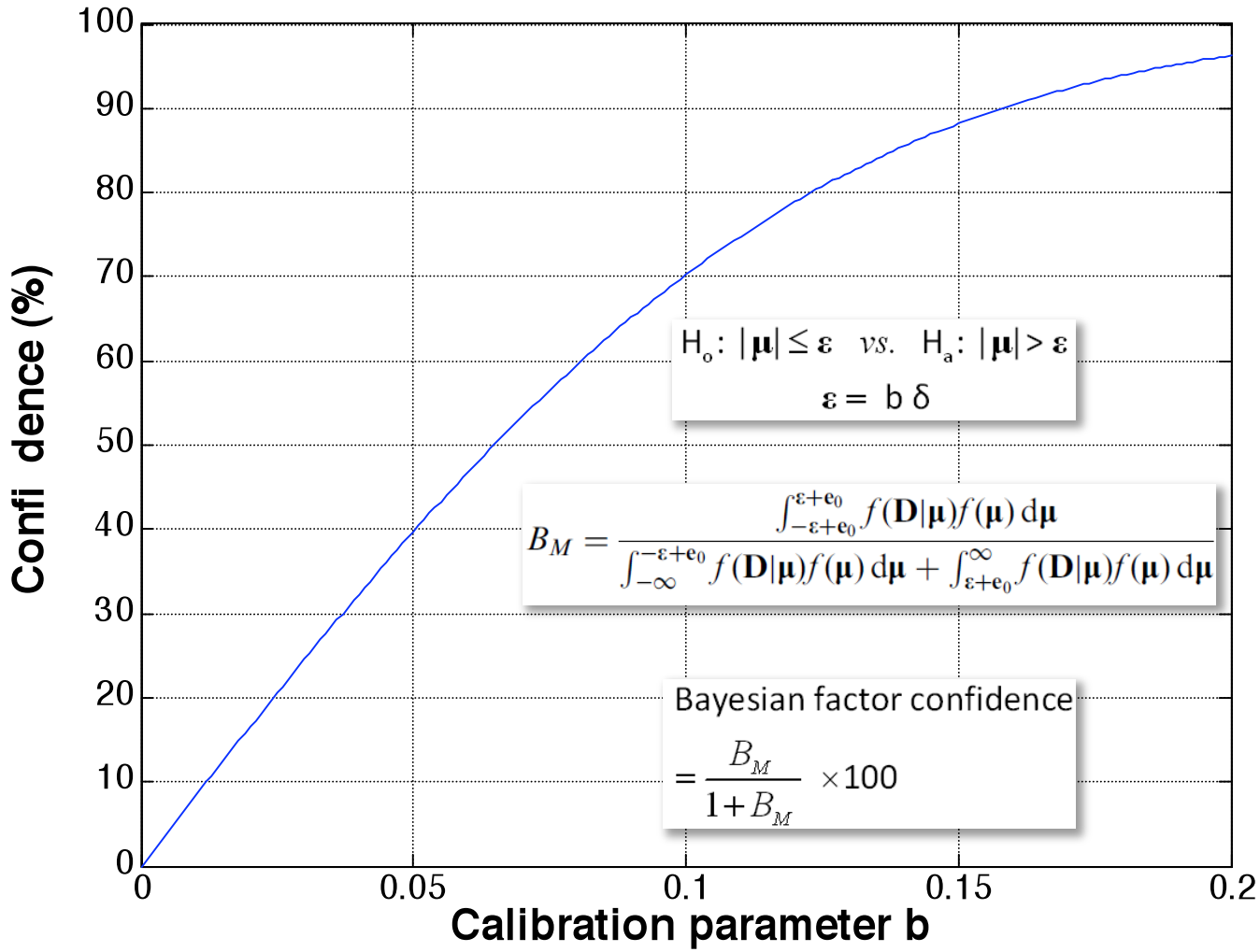
$B_M = P(\mathbf{d}|H_o) / P(\mathbf{d}|H_a)$ (likelihood ratio)

∨

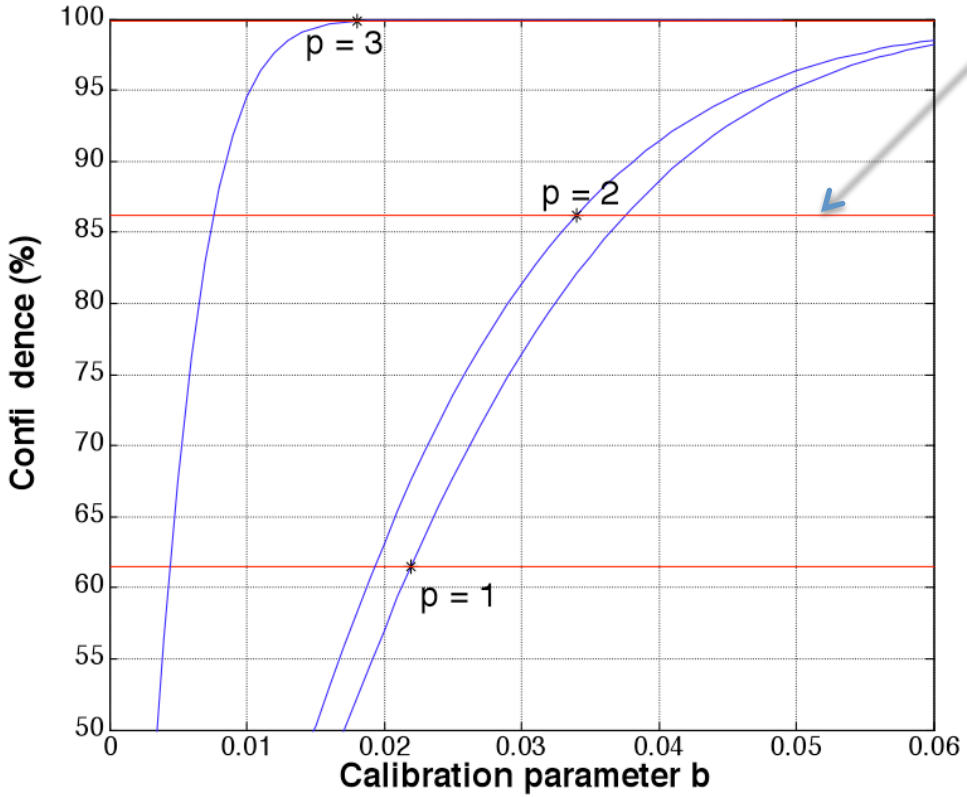
BF confidence quantification

$\kappa = B_M / (1+B_M) \times 100$

Calibration Parameter Selection



Calibration Parameter Selection

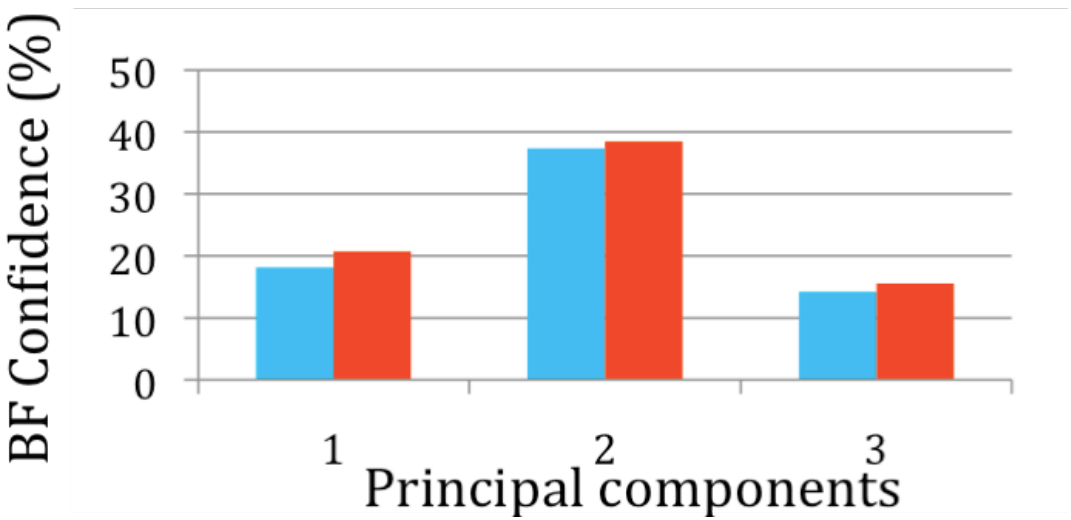


p = # of principal components

% of variability captured

Effect of Principal Components

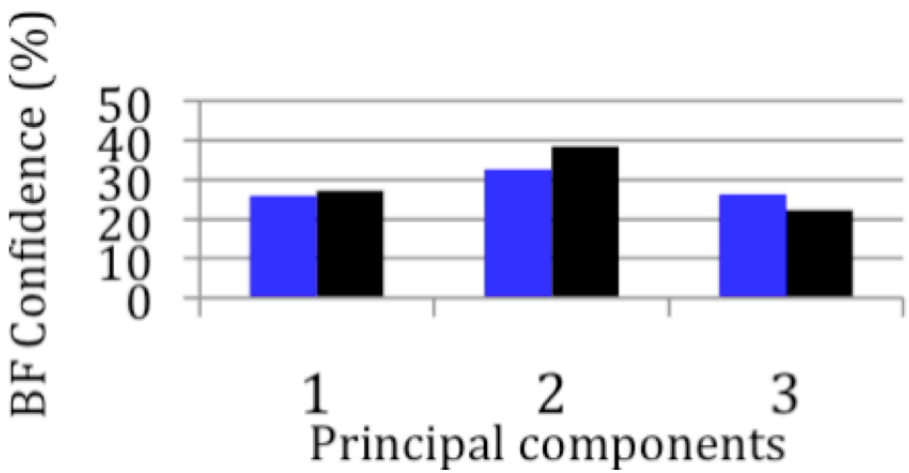
- Course 1



Blue = model 1
Red = model 2

Effect of Principal Components

- Course 2



Blue = model 1
Black = model 2

Closing Remarks

- Bayesian framework promising for validation
  - Incorporates statistics of field data
  - Incorporates statistics of M&S
  - Enables systematic evaluation of data variability
- Systematic method for accepting M&S
- Systematic method for comparing M&S
- Further refinement needed for calibration and sensitivity
- Further research required for accreditation use