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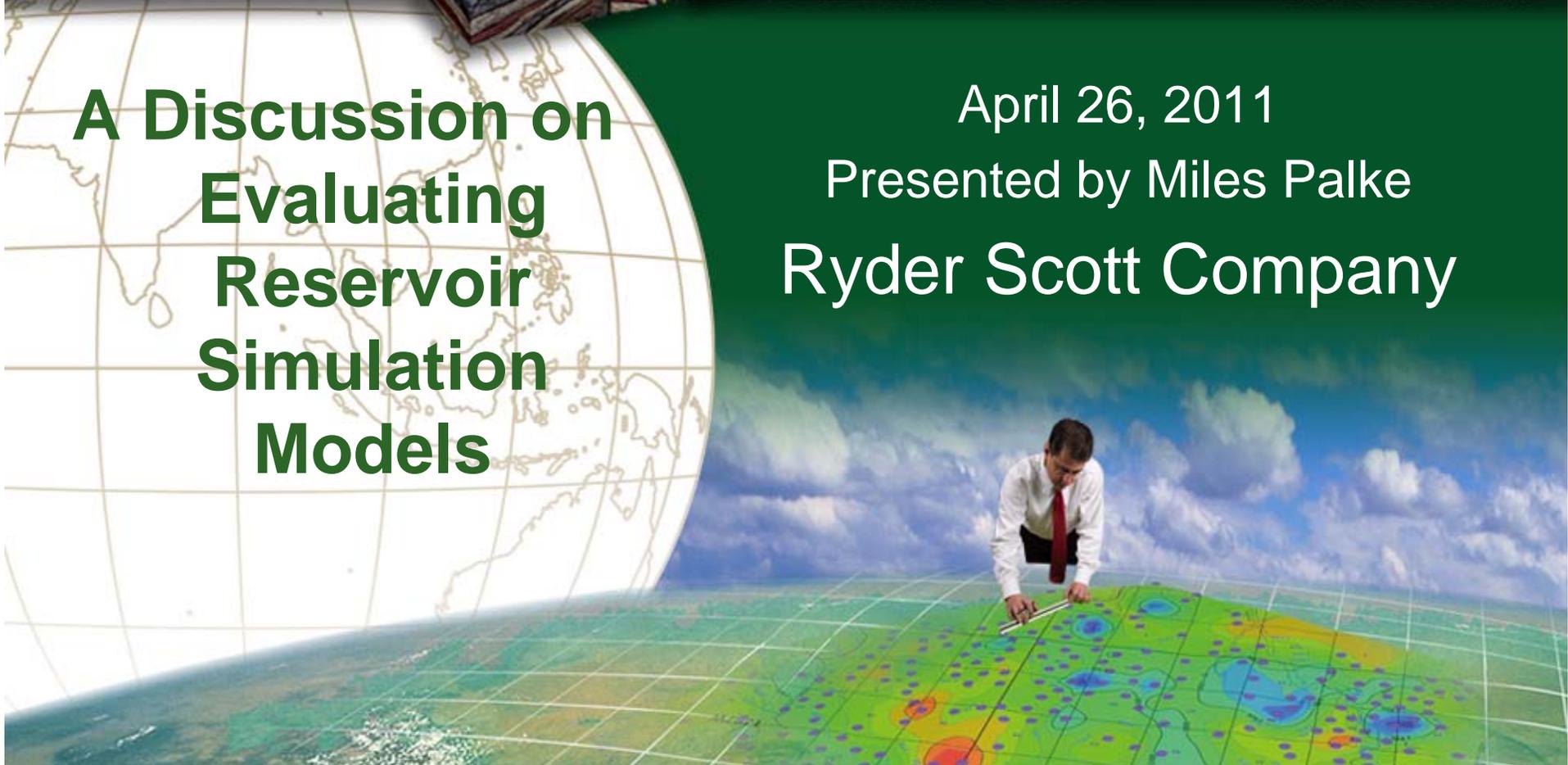


**A Discussion on
Evaluating
Reservoir
Simulation
Models**

April 26, 2011

Presented by Miles Palke

Ryder Scott Company



SPEE Presentation



Houston Chapter

DATE: Wednesday, May 4, 2011

TIME: 11:30 am

LOCATION: Petroleum Club – Coastal Suite

COST: Members: \$35.00
Guests & Non-members: \$40.00

Note: An additional \$5.00 surcharge will be added to payments of walk-ins and after deadline reservations.

SPEAKER: [Miles R. Palke](#)



Miles R. Palke is a senior petroleum engineer specializing in reservoir simulation, characterization and well-test and material balance analyses. He has more than fourteen years of reservoir engineering experience with heavy emphasis on reservoir simulation studies. Areas of expertise include sector and full-field reservoir modeling, fluid characterization, compositional simulation, coalbed methane recovery, gas storage analysis, nodal analysis, well test analysis and material balance evaluations.

Mr. Palke has evaluated numerous oil and gas properties around the world. Before joining Ryder Scott, he was a senior staff reservoir engineer and subsurface engineering manager at BHP Billiton for seven years beginning in 2002. He also worked at Ryder Scott from 1998 to 2002 as a petroleum engineer in the reservoir simulation group. Mr. Palke began his career as a petroleum engineer at Arco E&P Technology in 1996. He has BS and MS degrees in petroleum engineering from Texas A&M University and Stanford University, respectively. Mr. Palke is a Registered Professional Engineer in the State of Texas.

SUBJECT:

“A Discussion on Evaluating Reservoir Simulation Models”

Reservoir simulation is an increasingly prevalent tool used in our industry today, and engineers are frequently faced with the need to evaluate simulation models that they did not create. This happens not only in consultancies but also within E&P companies as well. In many cases, models built for a certain purpose by another party need to be considered for different purposes.

In this presentation, Mr. Palke will discuss the experiences of Ryder Scott in evaluating models, in particular for reserves estimation, and some of the pitfalls that have been encountered. Furthermore, Mr. Palke will discuss work underway at Ryder Scott to streamline, make consistent, and remove subjectivity from the model evaluation process

For reservations, please contact BK at (713) 651-1639, fax (713) 951-9659, or e-mail BKSPEE@aol.com by noon Monday May 2nd. Cancellations must be made prior to the noon May 2nd deadline. No shows will be billed. Cash and check payments are accepted. Credit cards can not be processed. Receipts provided upon payment.



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AFTER?
WHO KNOWS?*

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Evaluating Simulation Models



- Outline
 - Reservoir Simulation – Brief
 - Reviews – Why?
 - Brief Summary of Publications
 - Reviews – How?
 - Model Construction
 - Model History Match
 - Reviews – tricks, cheats, and examples
 - Future of Model Reviews

Reservoir Simulation – Brief

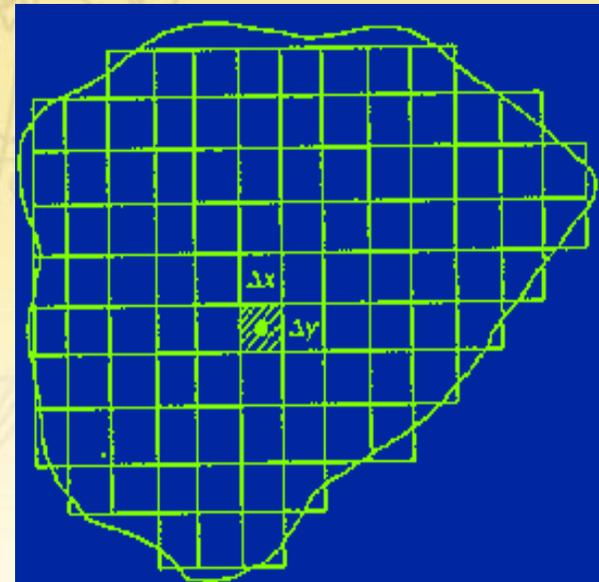
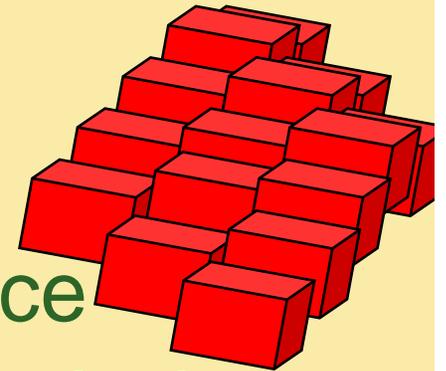


“Numerical reservoir simulators are used widely, primarily because they can solve problems that cannot be solved in any other way. Simulation is the only way to describe quantitatively the flow of multiple phases in a heterogeneous reservoir having a production schedule determined not only by the properties of the reservoir, but also by market demand, investment strategy, and government regulations”

Mattax and Dalton, “Reservoir Simulation”, SPE Monograph 13 (1990)

Reservoir Simulation – Brief

- What is Reservoir Simulation?
- Numerical Model of Reservoir
- Predictor of Reservoir Performance
- Combines Several Methods of Analysis
 - Material Balance
 - Fluid Flow Mechanics
 - Geological Model
 - Vertical Flow Perf.
 - Pipeline Networks



- The “Powers” of Reservoir Simulation
 - Correct Physics of Fluid Flow
 - PVT Strictly Enforced
 - In Each Cell and Not Averaged
 - Variable Rock Properties
 - Vertically and Areally
 - Detailed Calculations
 - Calculations Don’t Assume Global Average Volume

Reservoir Simulation – Brief



- Uses of Reservoir Simulation
- Reservoir simulation is an indispensable tool for:
 - reservoir management
 - recovery prediction
 - process design
 - strategic planning
 - testing impacts of reservoir parameters whose values are uncertain

Reservoir Simulation – Brief



- Uses of Reservoir Simulation
- “What If” Scenarios
 - Can Test Various Development Alternatives
 - Can Test The Impact of Uncertain Reservoir Parameters

Reviews – Why?

- Decision Relying on Model
 - Production Planning and Scheduling
 - Reserves Estimation
 - Investment Decisions
 - Changes to Field Operations
- Is the Model Appropriate for these Purposes?

Reviews – Why?



- Necessary Because
 - Models are history matched
 - Changes to description are usually part of history matching
 - Controls used during model predictions are “flexible” and largely determine outcome
 - Most decisions are not made by people who are already intimately familiar with the model in question
 - Many times – there is no one available who was involved in the model construction or history matching!
 - Models can become stale and out of date, and no longer fit for purpose
 - Models are INEVITABLY used for purposes beyond those they were designed for

Brief Summary of Publications



- Several papers by the Presenter and Associates on this topic
- Virtually no literature on the application of simulation results to reserves estimation
- SPE 71430
 - “The Adaptation of Reservoir Simulation Models for Use in Reserves Certification Under Regulatory Guidelines or Reserves Definitions”
- SPE 96410
 - “Reservoir Simulation and Reserves Classifications-Guidelines for Reviewing Model History Matches To Help Bridge the Gap Between Evaluators and Simulation Specialists”
- SPE 110066
 - “Case Studies Illustrating the Use of Reservoir Simulation Results in the Reserves Estimation Process”

“The Adaptation of Reservoir Simulation Models for Use in Reserves Certification Under Regulatory Guidelines or Reserves Definitions” - 2001

- First SPE paper specifically addressing application of simulation to reserves estimation
- Highlights:
 - Most simulation models are based on a 2P or P50 outlook on the reservoir
 - Adapting such models for Proved can be handled by
 - Changing the model, or
 - Changing the output
- Models of immature reservoirs are more uncertain than models of mature reservoirs
 - Immature processes in mature reservoirs may still be uncertain
 - History matches of mature reservoirs are critical to assessing quality or certainty

“Reservoir Simulation and Reserves Classifications-Guidelines for Reviewing Model History Matches To Help Bridge the Gap Between Evaluators and Simulation Specialists” - 2005

- Explains (briefly) the process of history matching
 - Provides a detailed 9 step process to evaluate a history match
 - Describes simulation models as “analogies” to the reservoir
 - Describes in detail the importance of reviewing the transition from history to prediction and the importance of the “Status Quo Case” – discussed later
- 1) “... the results of a simulation model should be taken into consideration along with all other data available for the field under review.
 - 2) The results of a model should not be used to replace good, reliable data or reasonable engineering judgment. Comparisons with traditional analytical techniques ... should be undertaken to provide the model with a much needed “reality-check”....
 - 3) Models constitute analogies to actual reservoirs, and should be treated as such.
 - 4) A “status quo” model run in which the model transitions from history match to predictive mode assuming no material change in the operating parameters is a good tool to assess the history match and the validity of a model.
 - 5) Assessing models is not a clear-cut proposition. Rather model validity should be assessed within the specific context of what purpose the results are desired to fulfill.”

“Case Studies Illustrating the Use of Reservoir Simulation Results in the Reserves Estimation Process” – 2007

- Three case studies presented for adaptation of simulation results to reserves cases
 - Mature reservoir modification of simulation output
 - Mature reservoir modification of simulation input
 - Immature reservoir simulation results combined with probabilistic approach
- “It is often impractical to build models solely for the purpose of estimating reserves. Models not built for estimation of reserves may still be used for reserves determination ... by the modification of results, modification of input, and through the use of probabilistic sensitivity studies. Some models ... may be unsuitable for quantitative reserves forecasting regardless of what adjustments are applied.
- Further work needs to be conducted by both the industry and regulatory bodies to definitively prescribe procedures for the use of models ... in the reserves process.
- The concept of considering a simulation model as an analog is easier to apply to a mature field ... rather than to an immature field with little to no production history.
- In the case of the immature reservoir, the range of uncertainty in the results should be adequately reflected by the range of hydrocarbon ultimate recoveries.....”

Tips & Tricks of the Trade

- The results of a simulation model should be taken into consideration along with all other data available for the field under review
- The results of a model should not be used to replace good, reliable data or reasonable engineering judgment. Comparisons with traditional analytical techniques should be undertaken to provide the model with a much needed “reality-check”

Tips & Tricks of the Trade

- Start by considering the purpose the model was built for, and the purpose you are reviewing the model for
 - What are the potential disconnects?
- Always treat the model as an analogy to the actual field.
 - The quality of the analogy depends on the degree to which
 - The model construction honors the known data, and
 - The quality of the history match

Reviews – How?



- Two main, separate facets of any model require consideration.
- Model Construction:
 - How accurate and detailed is the static model?
 - Does it honor observed data from well control?
 - Are the fluid treatments reasonable?
 - Does the grid have sufficient resolution to address the questions asked?
 - Is the initialization of the model reasonable?
 - Have wells placement and completed intervals been captured correctly?

Reviews – How?



- Two main, separate facets of any model require consideration.
- History Match:
 - Is the history match reasonable?
 - What data was used to match history?
 - How adequate is the match of the simulated values to the observed values?
 - What changes were required to the description during history matching to secure the history match? Are these changes justifiable?
 - How well does the model transition from history to prediction?

Tips & Tricks of the Trade

In reviewing history match consider whether changes are reasonable

- Parameters may be adjusted during history matching that have a modest impact on the history, but a significant impact on the prediction
- Simulation software allows changes to be made which may well be unreasonable
- History match changes may be appropriate for certain purposes but not for others
 - Modifying the properties immediately around each well individually
 - May be okay for forecasts of existing wells
 - Probably inappropriate for infill wells

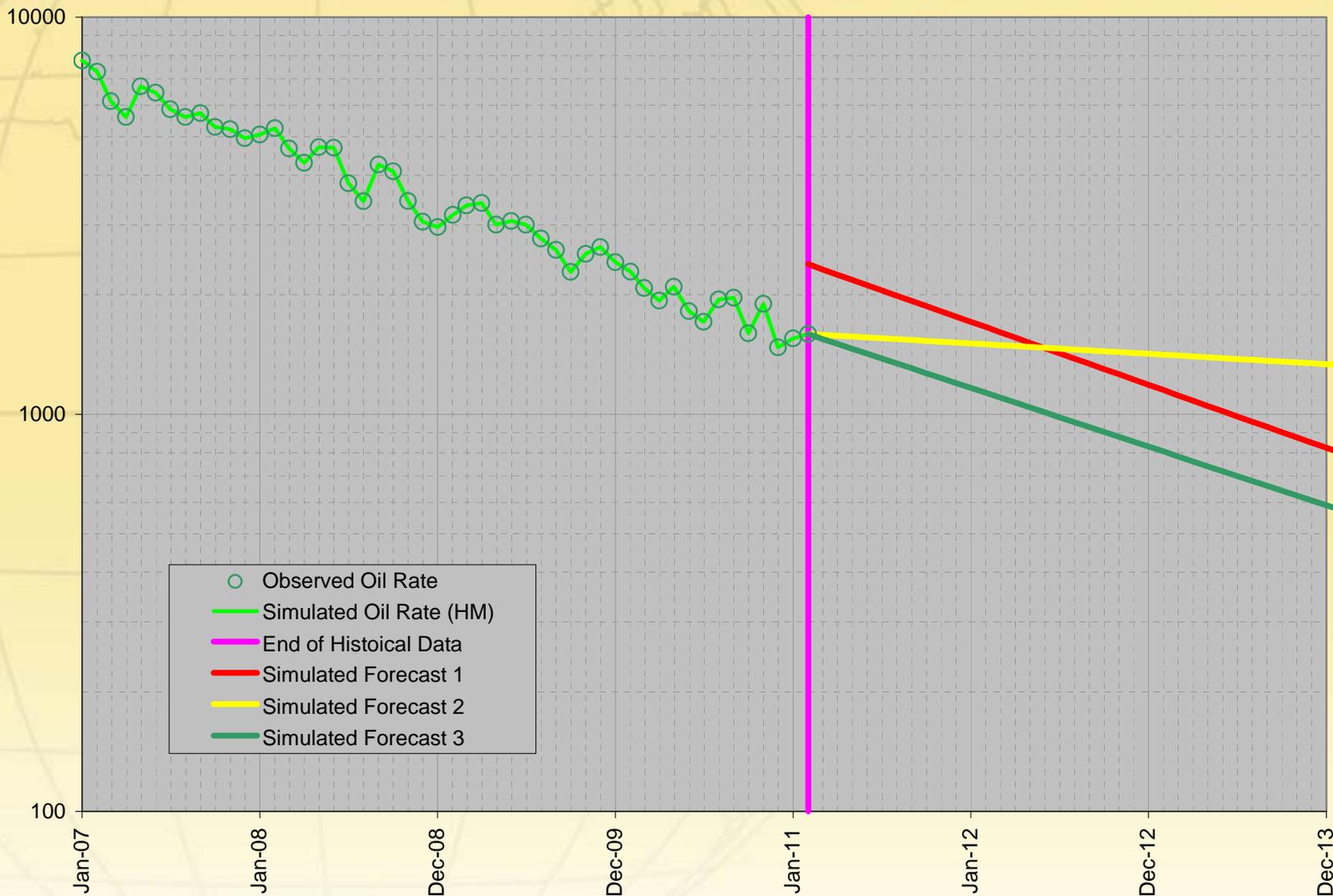
Tips & Tricks of the Trade

- Do not be tricked by very good matches of single phases, or cumulative volumes at the end of history
 - It is typical to fix the dominant phase's rate(s) so that the simulator must make those volumes
 - Cumulative volumes at the end of history can be matched while completely missing the boat on trends during history – therefore making the predictions less useful
- Always carefully review how the model transitions from simulation to prediction
- Always carefully review the “reasonableness” of the Status Quo Case

Status Quo Case

- Simulation Modeling has three primary phases:
 - Static Model Construction
 - History Matching/Calibration
 - Prediction
- When prediction starts, the controls imposed on the wells/group/field normally change from controlling on set rates to controlling on set pressures
- Often requires uncalibrated well productivities to be calibrated

Status Quo Case



Cheats & Examples

- Simulation Software usually allows unreasonable and unjustifiable features to be placed in models
- Examples Include
 - Pore volumes that exceed gross volumes
 - $\Phi > 100\%$, $NTG > 100\%$
 - Aquifers where none exist
 - Pipelines of cells connecting disconnected volumes
 - Residual saturations of 0%
- Enterprising engineers can abuse these possibilities
- Novice engineers may not be aware that these “gremlins” exist in their model
- Some simulation engineers view using such tricks as “par for the course”

Cheats & Examples

- Pore Volume Multipliers
- Well-by-well adjustments
- The “Gasifer”

The Future of Model Reviews



- There will be increasing need for model reviews
 - More frequent model construction
 - More frequent exchange of assets between companies that rely on simulation
 - More frequent movement of staff
- Consistency in model reviews will become more important as these reviews are depended upon to justify:
 - Investments
 - Reserves booking

Conclusions



- Reviewing models is an increasingly important task for petroleum engineers
- Reviewing a model is not a simple task
- Reviewing models requires inspection of the construction of models and the history match of the model
- Model reviews should be fit for purpose and include a review of the original purpose the models were built for
- More work remains to create more consistent and quantitative approaches

Thanks



- The presenter thanks the SPEE and RSC for the opportunity to present these ideas
- The presenter thanks his co-author and the colleagues at RSC