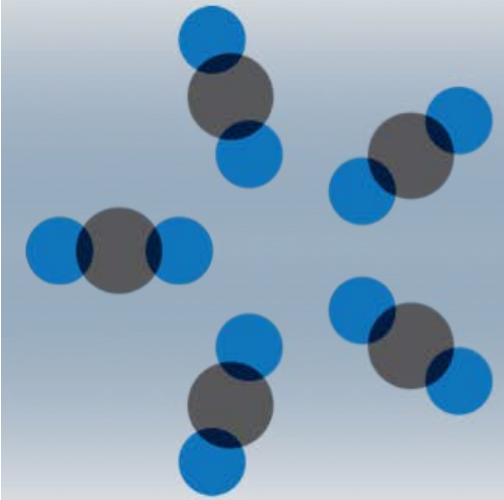


CCSI^2

Carbon Capture Simulation for Industry Impact

CCSI Partnership Evolution – CCSI2 Industry and Academic Advisory Board (IASB)

John H. Shinn, Coordinator CCSI2 IASB

Partnership has always been essential to the success of CCSI and will become even more so with CCSI2

- Emphasis changing as program developed
- Focus of program and partners changing accordingly
- This presentation…
  - Briefly recap history and changes
  - Examine current state and desired future state to fully capitalize on CCSI capability to support capture technology development programs
  - Overview of toolset value; demonstrations with partners

Shifts in Partnership Emphasis with CCSI Evolution

- Early Program
  - Focus on rapid tool development
    - how to most add value to capture tech development efforts
  - Partner role:
    - Direct program involvement in tool development
    - High-level programmatic advice, emphasis and re-direction
      - E.g. rapid deployment and test plan, IP approach, expansion from solid sorbents to solvents

- Mid-Program
  - Focus on early tool testing and evaluation
  - Partner role:
    - Test, evaluate, feedback on early tools
    - Identify key values
    - Recommend improvements
      - E.g. value of reduced order modeling tools (e.g. ALAMO) and integration of tools (e.g. FOQUS), propagating understanding of value of UQ

Many Partners - CCSI IAB and IASB Members

ADA Environmental
Alstom
Babcock and Wilcox
Babcock Power
Chevron
Eastman Chemical
Fluor
GE
Process Systems Enterprise, Inc.
Southern Company
URS
Air Products
ANSYS, Inc.
ExxonMobil
Invensys
Phillips
Southern California Edison

AEP
Ameren
AspenTech
Boeing
Burns and McDonnell
Duke Energy
Dupont
PG&E
Ramgen
Symantec
Worley Parsons
WS-Corp
GSE Systems
ChemStations
Cybernetica

EPRI
CO2CRC
Sintef
Uniper
CSIRO
EERC

SRI
UT Austin
UC Berkeley
Carnegie Mellon
West Virginia University
U Kentucky
NTNU Norway
U Melbourne

Some Initial Tools and Value

- ALAMO
  - Provides high accuracy predictions based on complex model outputs and datasets while reducing computational complexity to permit optimization and other complex tasks

- Uncertainty Quantification (UQ)
  - Creates more robust fitting by more completely exploring possible values of key model parameters that best fit experimental dataset
  - Allows estimation of error of model predictions by varying values of key parameters across most probable range
  - Enables focused experimental design to maximize learning, minimize prediction uncertainty

- FOQUS
  - Links complex models to allow single runs
  - Permits large numbers of runs for single models to be executed at one session (e.g. Optimization runs of ASPEN simulations)
  - Fully Integrates reduced order modeling and uncertainty quantification

CCSI2 Moves to Deployment Emphasis

- Program focus moves to utilization
  - Deploy tools to broad suite of capture development programs to accelerate rate of RD&D
  - Ensure long-term toolset support
  - Broaden toolset availability through Open Source and commercial routes

- Key objectives…
  - Create the highest value for the capture tech development programs by integrating the power of the CCSI toolset
  - Apply across a broad set of programs from low-TRL to demonstration runs
  - Further improve tools through greatest integration of broadest possible datasets and intentional design of test programs

- Partners
  - Those with greatest investments in tech development
    - Initially mid-scale test programs (e.g. ADA Environmental, Alstom, GE),
    - Expanded to demonstration programs (NCCC, UT test programs, Mongstad (TCM)),
    - Integrated to next-generation lab-scale programs (e.g. MECS)

Keys Values of CCSI Partnership in Development Programs

- Accelerate development by
  - Design of Experiments - Creating test plans that more fully integrate prior data and create highest value-add from additional testing
    - CCSI UQ-integrated tools enable identification of key gaps, highest value-add data making test programs far more effective
  - Creating Gold-Standard Models best representing various technologies.
    - Tools enable complete integration of collected data with data sources from all scales and other operations
  - Most rapid integration of complete test-run data into most advanced models
    - Accelerates improvements in design, system integration, optimization
    - Enables equal comparison of various technology approaches
    - Supports more rapid and more certain decisions to advance to next scale

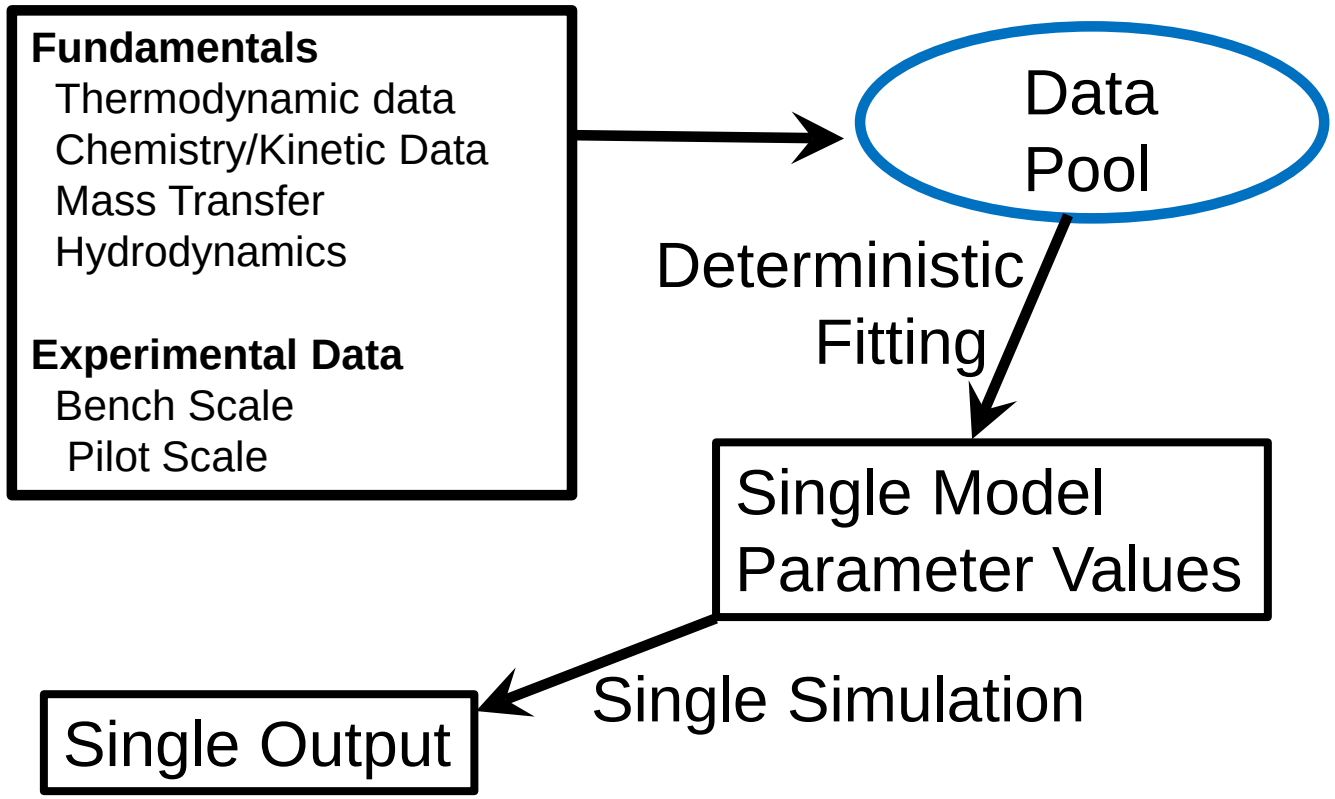
CCSI² Industrial Collaboration & Contributions

- **Industrial Collaborations**
  - 7 CO_2 Capture Program projects $40MM+ in total project value (TRL 3-7)
  - 6 additional external industrial agreements (executed or in progress)
    - Cooperative R&D Agreement: GE, ADA-ES, Ion, TCM, SINTEF
    - Contributed Funds Agreement: COSIA ($500k)
  - Includes enabling capture technology support:
    - Aerosol, dynamic characterization, turndown, advanced process control

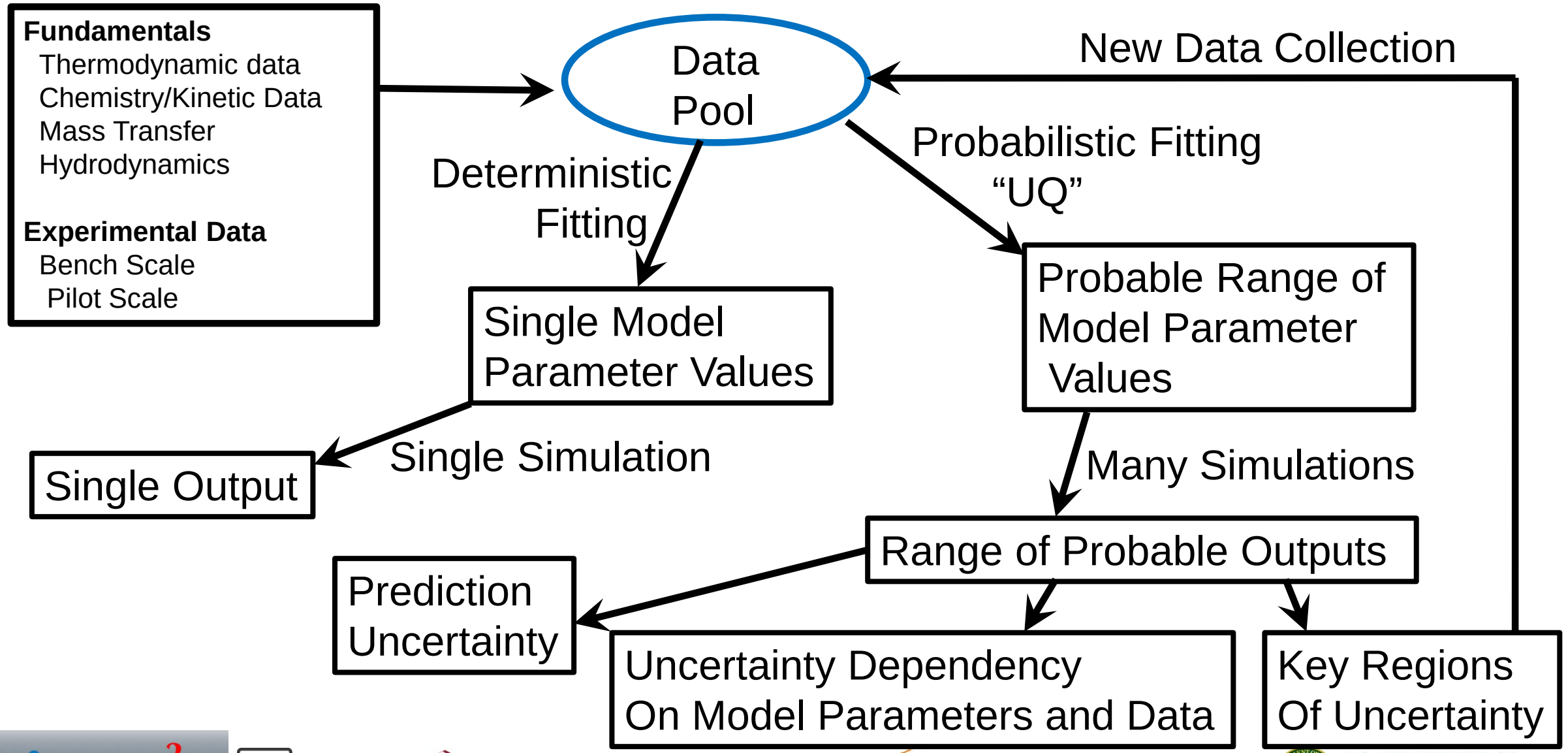
- **Optimal Design of Experiments (multiple programs)**

- **Improved solvent modeling framework/ Gold Standard MEA Model (SINTEF/TCM/NCCC)**

Changing the Development Game through Modeling



Changing the Development Game through Modeling



CCSI Toolset - A True "Game Changer"

- Before CCSI…
  - High-conversion and steady-state operations focus of test runs
  - Modeling programs done after testing; focused on individual operation datasets
  - Mostly deterministic data fitting

- With CCSI
  - Integrated modeling and experimental design with full probabilistic fitting (UQ)
    - Optimal improvement testing integrated with other demonstration demands and practicalities
    - Allows best process improvement, design, optimization
  - Dynamic performance testing during operating state changes
    - Enables dynamic modeling, state-change predictions, process control
  - Full integration of data and uncertainty from related operations, different scales
    - Better models, better ability to compare technologies
  - Modeling and testing of pragmatic performance issues e.g. aeresols, packing

CCSI2 Tech Program Presentations This Week

- Wed AM
  - Accelerating Development:
    CCSI2 Partnerships with Capture Tech Development programs.
    - MECS – Low TRL tech development partnership
    - Modeling applications to very practical operation issues
      - Aerosol Formation
      - Packing performance
    - Maximizing value of large scale tests (NCCC, TCM)
    - Making our tools available (Open Source distribution plan)

- Weds PM
  - More examples of toolset applications to improve tech development
    - Successes, managing practicalities
  - Development of “Gold Standard” model for MEA

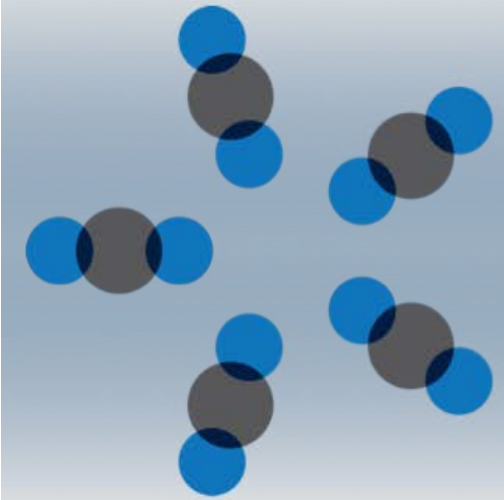
CCSI2 Tech Program Presentations This Week

- Thurs AM and PM
  - Exploratory capture programs interfacing with CCSI
  - Demonstrations of tools
    - hands-on opportunities, partnership discussions
  - Panel – Future of tech development with combined modeling/experimentation

New Members and Partners Welcome!

- Get the most out of your technology development investments.

- Annual Workshops
- Monthly concalls
  - Toolset applications to tech development programs
  - New capabilities and results
- Support in toolset exploration and implementation
- Development of maximum value-add partnerships



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Carbon Capture Simulation for Industry Impact

For more information
https://www.acceleratecarboncapture.org/

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