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NREL
National Renewable Energy Laboratory

Incorporating Monte Carlo Analysis Into Techno-Economic Assessment of Corn Stover to Ethanol

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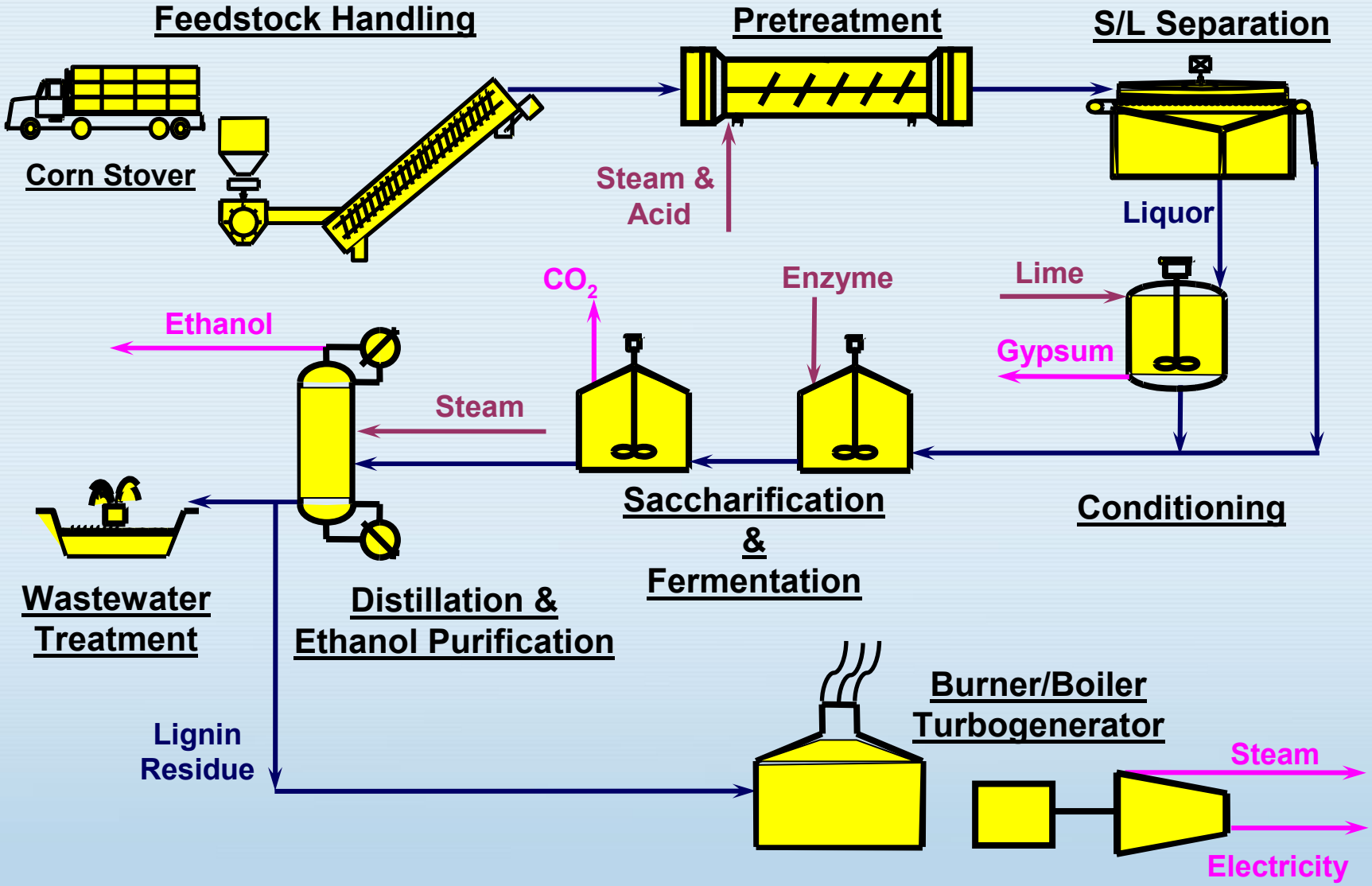
Mark F. Ruth and John L. Jechura
National Renewable Energy Laboratory

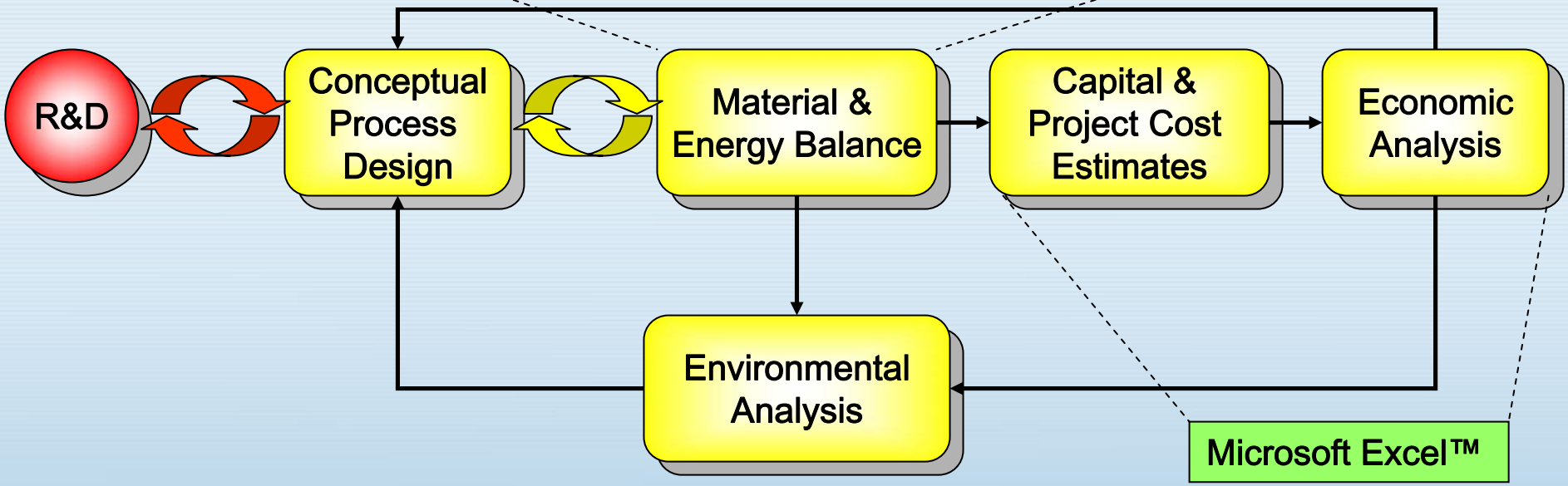
Operated for the U.S. Department of Energy by Midwest Research Institute • Battelle

Corn Stover to Ethanol Process

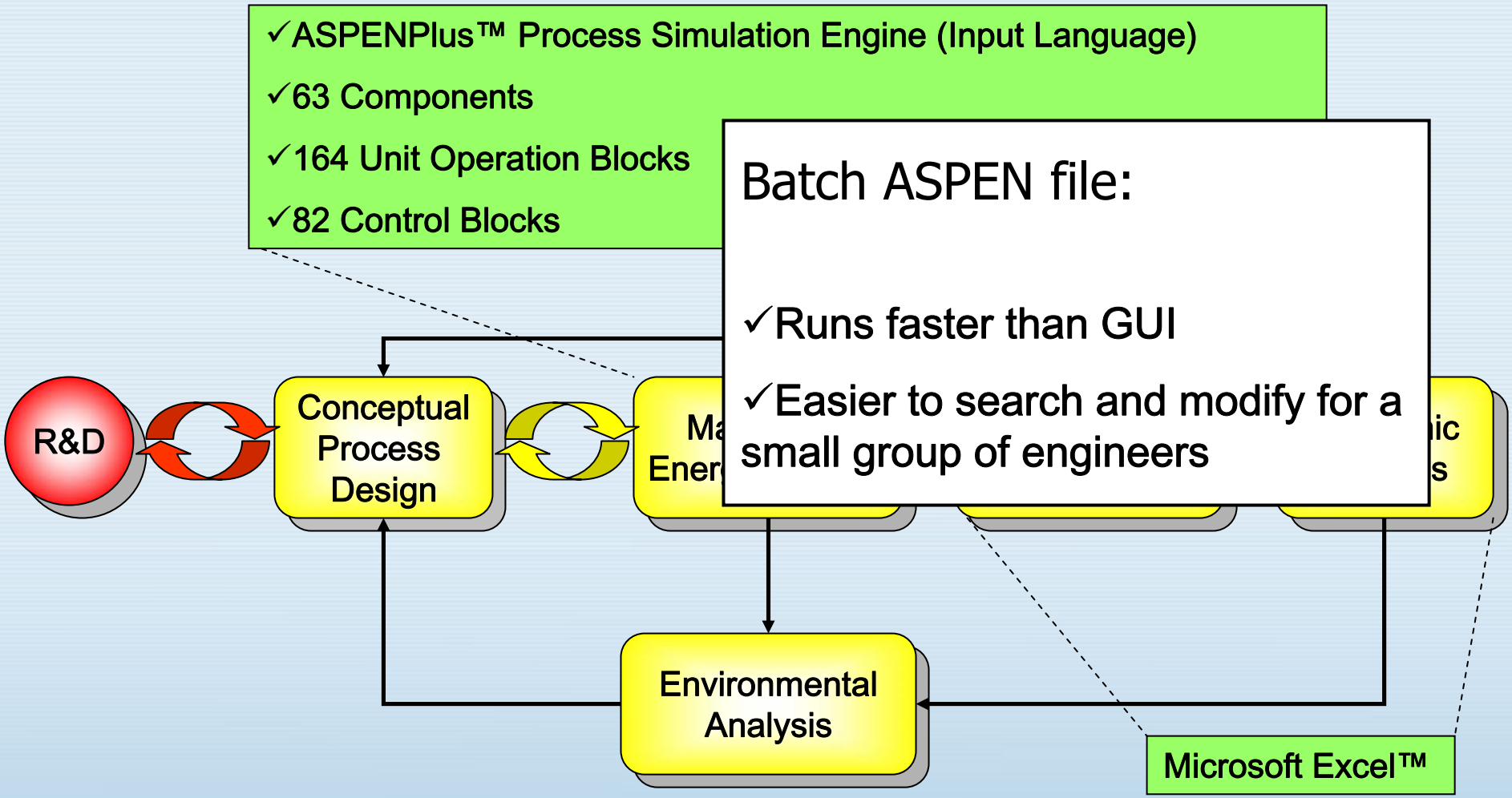


Process Analysis Technique

- ✓ASPENPlus™ Process Simulation Engine (Input Language)
- ✓63 Components
- ✓164 Unit Operation Blocks
- ✓82 Control Blocks



Process Analysis Technique



Technoeconomic Model

- In 2002, NREL published an updated target-case design report
  - Greenfield corn stover to ethanol process
  - NREL/TP-510-32438
  - www.nrel.gov/docs/fy02osti/32438.pdf
- Minimum Ethanol Selling Price ($ per gallon ethanol) is the primary result

Design Case Economic Results

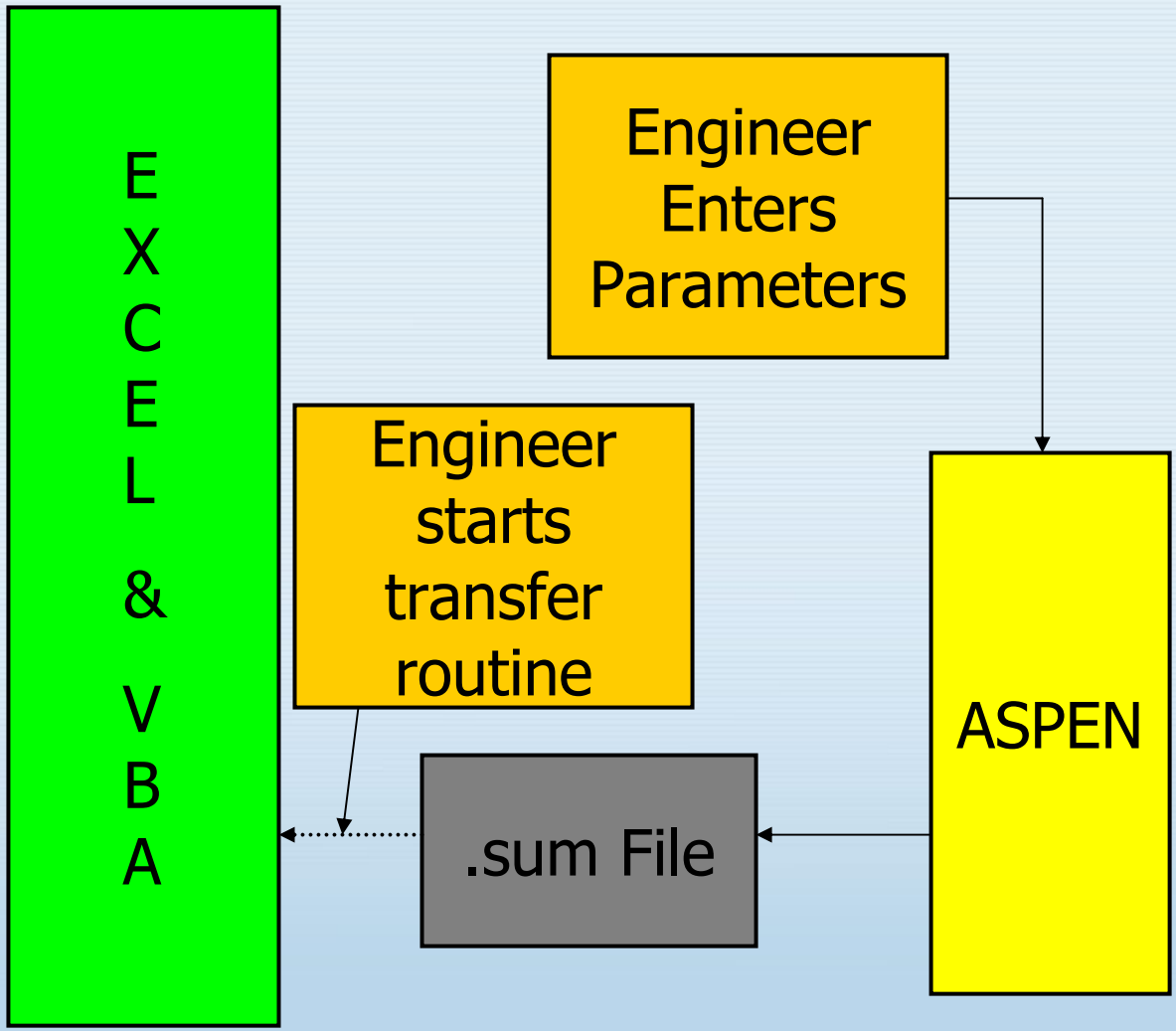
Plant Size: 2200 tons (2000 MT) Dry Corn Stover/Day (Greenfield Site)
Corn Stover Cost: $30/dry ton

Economic Parameter (Units, $2001)	Value
Minimum Ethanol Selling Price ($/gal)	$1.07
Ethanol Production (MM gal/yr)	69
Ethanol Yield (gal/dry ton stover)	90
Total Project Investment ($ MM)	$197
TPI per Annual Gallon ($/gal)	$2.86
Production Cost ($/gal)	$0.58

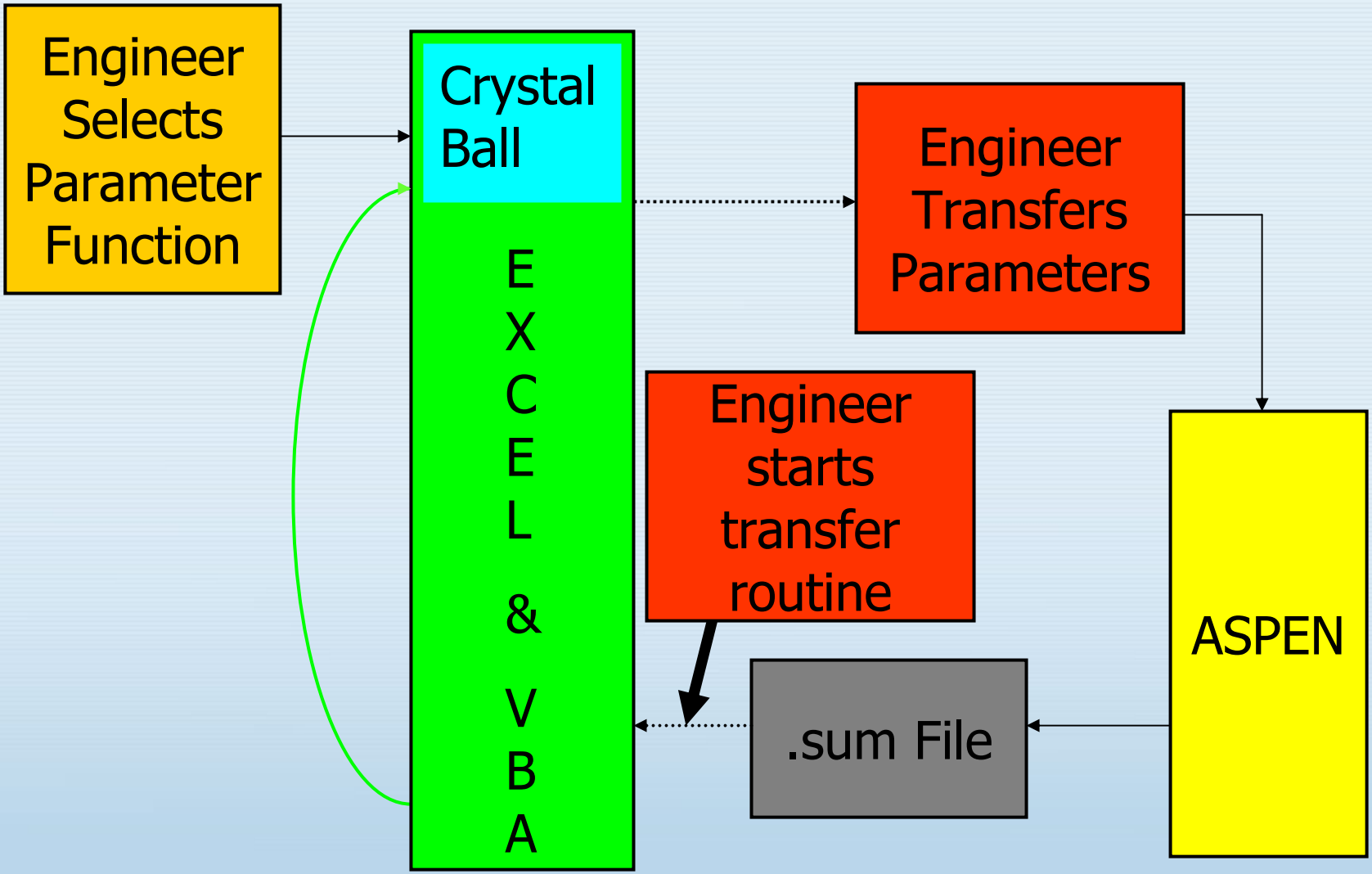
Monte Carlo Analysis

- Uses random numbers within defined probability functions to predict the uncertainty of modeled systems
  - Packaged software (e.g., Crystal Ball) makes it easier with Excel
- Used in the environmental, safety, business and other fields

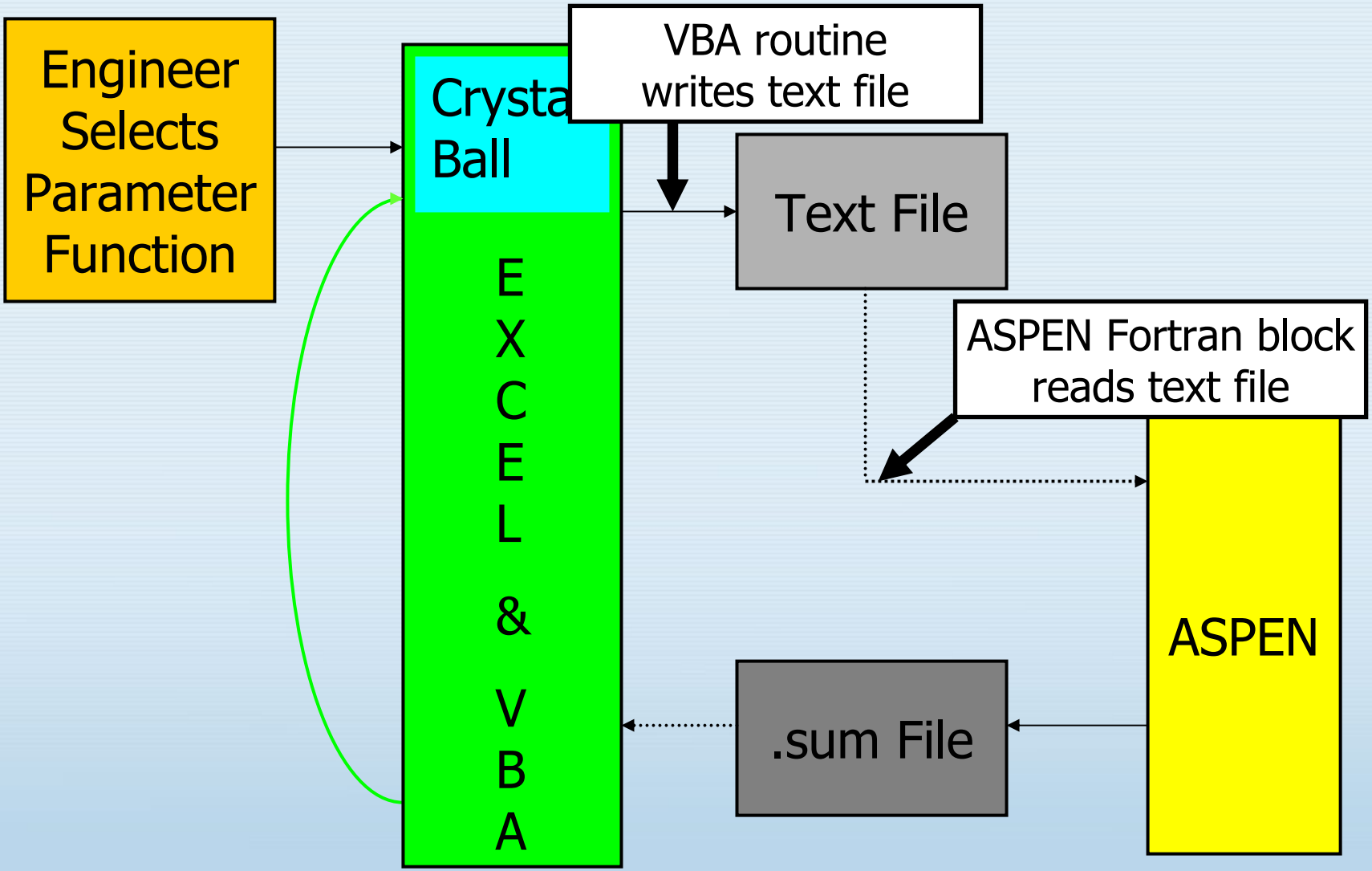
Use of ASPENPlus™



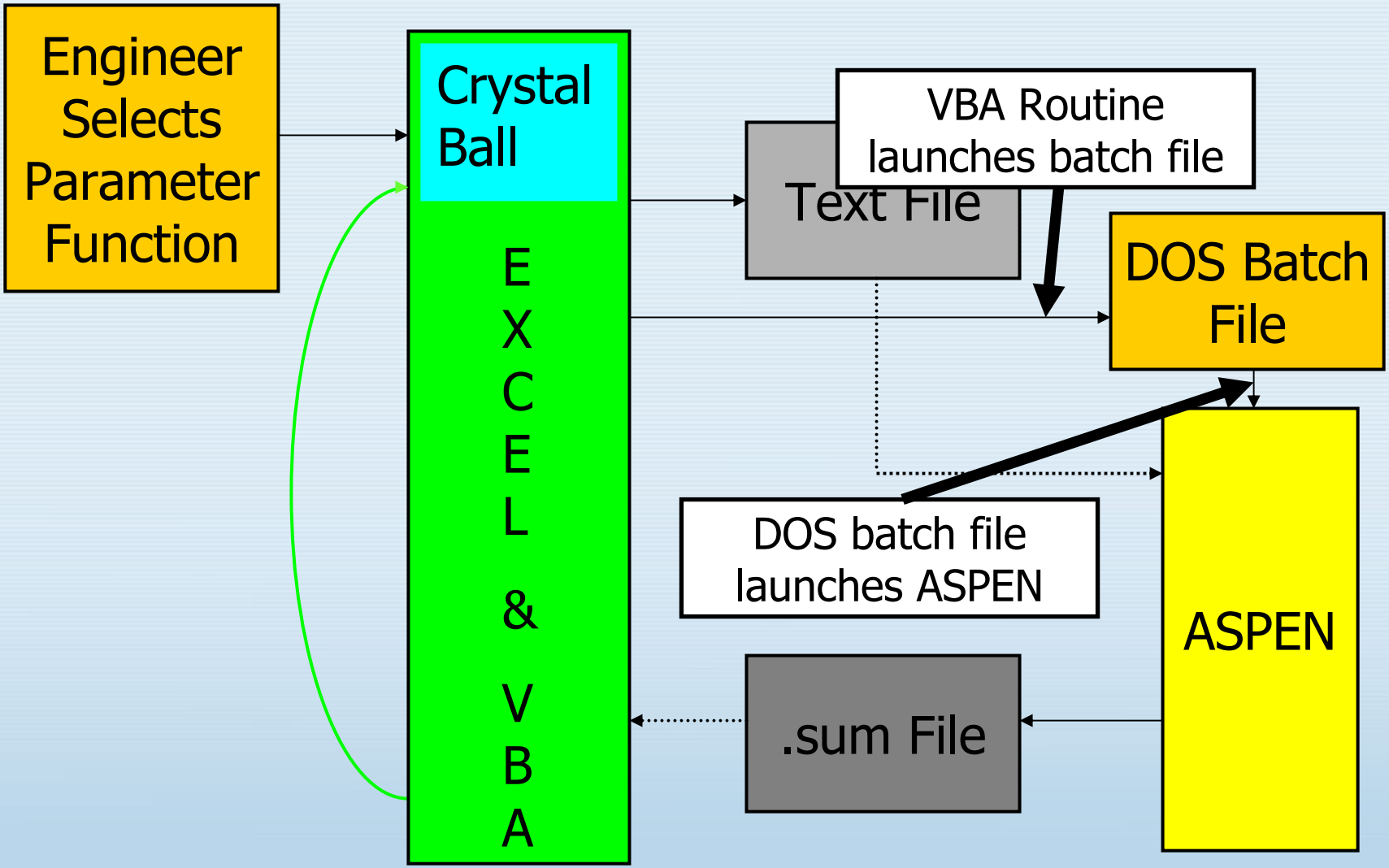
Initial Monte Carlo Technique



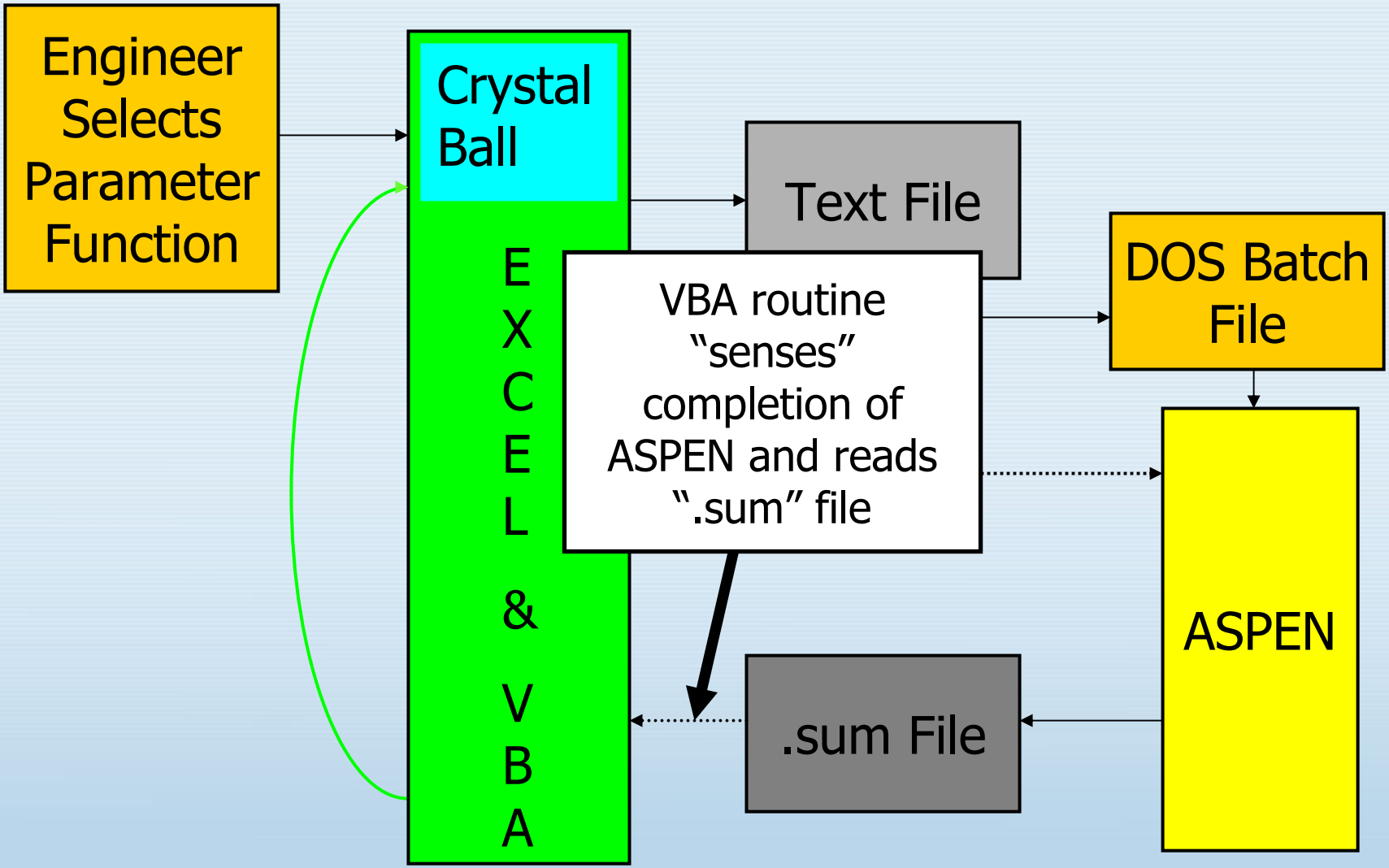
Monte Carlo Technique



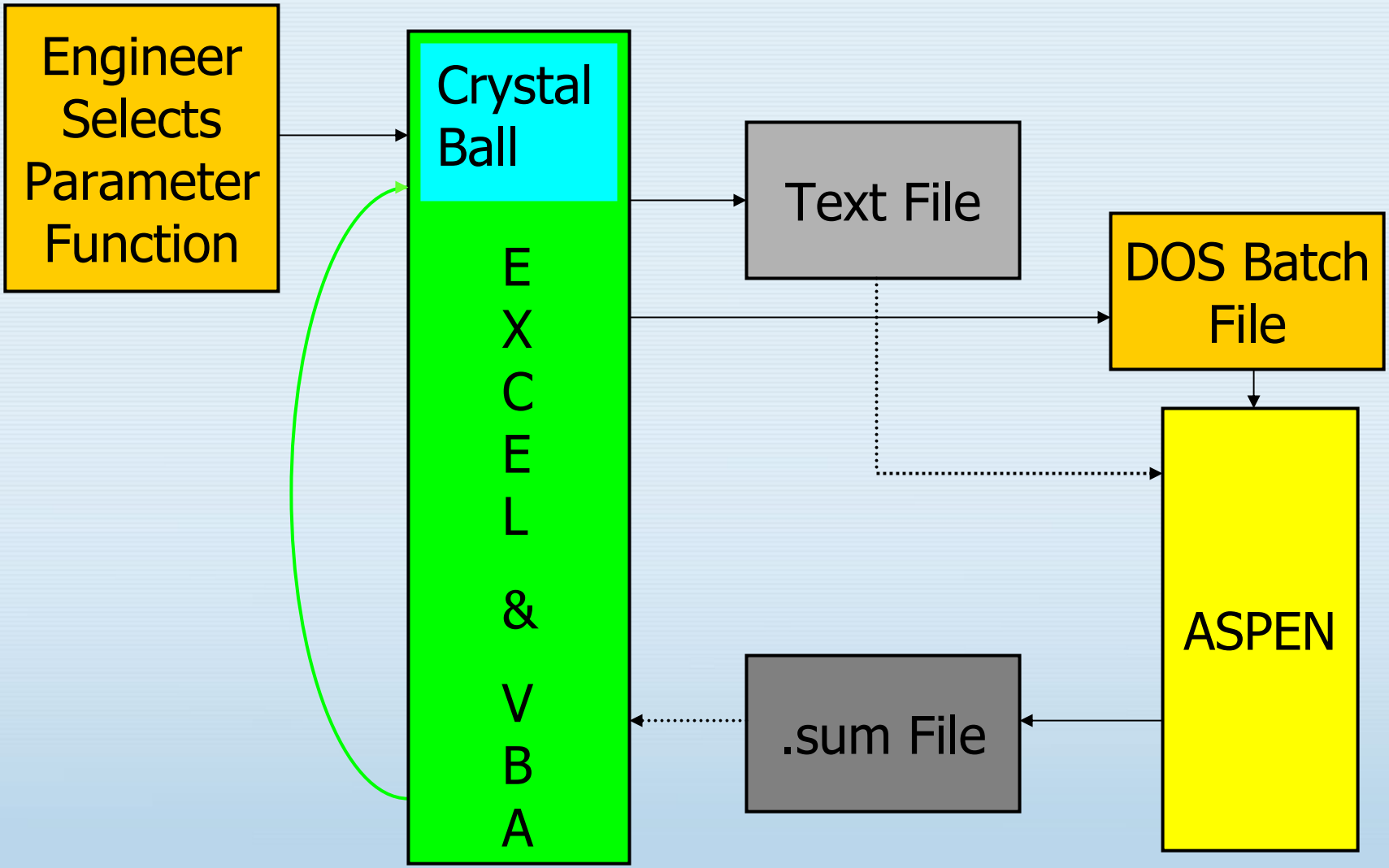
Monte Carlo Technique



Monte Carlo Technique



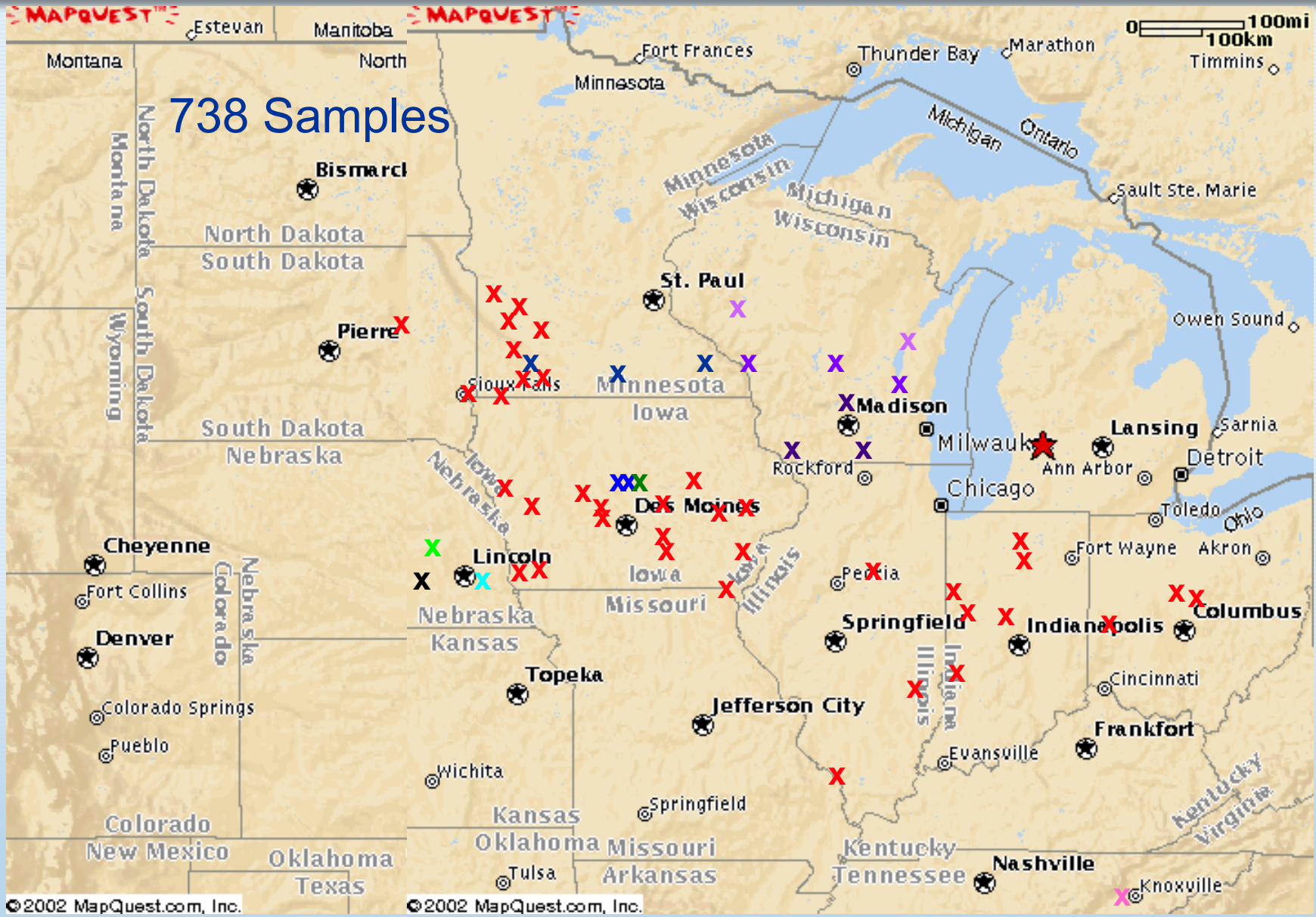
Monte Carlo Technique



Probability Distributions

- Feedstock variability
  - Measured data
- Yields
  - Estimated probability functions

Corn Stover Collection Locations



Stover Composition Ranges

	Structural Glucan	Xylan	Lignin	Protein	Acetyl	Uronic Acids	Structural Inorganics (Silica, Ash)	Soil	Soluble Solids	Total
Minimum (% dry wt.)	27.9	14.5	11.5	1.3	0.9	1.4	-1.2	0.9	2.0	90.0
Maximum (% dry wt.)	39.6	25.5	20.4	7.0	3.9	3.9	10.2	1.7	19.6	101.9
Span (% dry wt.)	11.7	11.0	8.9	5.7	3.0	2.5	11.3	0.8	17.5	11.9
Mean (% dry wt.)	33.8	20.0	15.8	3.6	2.7	2.9	4.2	1.3	8.2	97.4
Standard Deviation (% dry wt.)	2.0	1.6	1.4	0.7	0.5	0.3	1.6	0.1	2.2	1.7

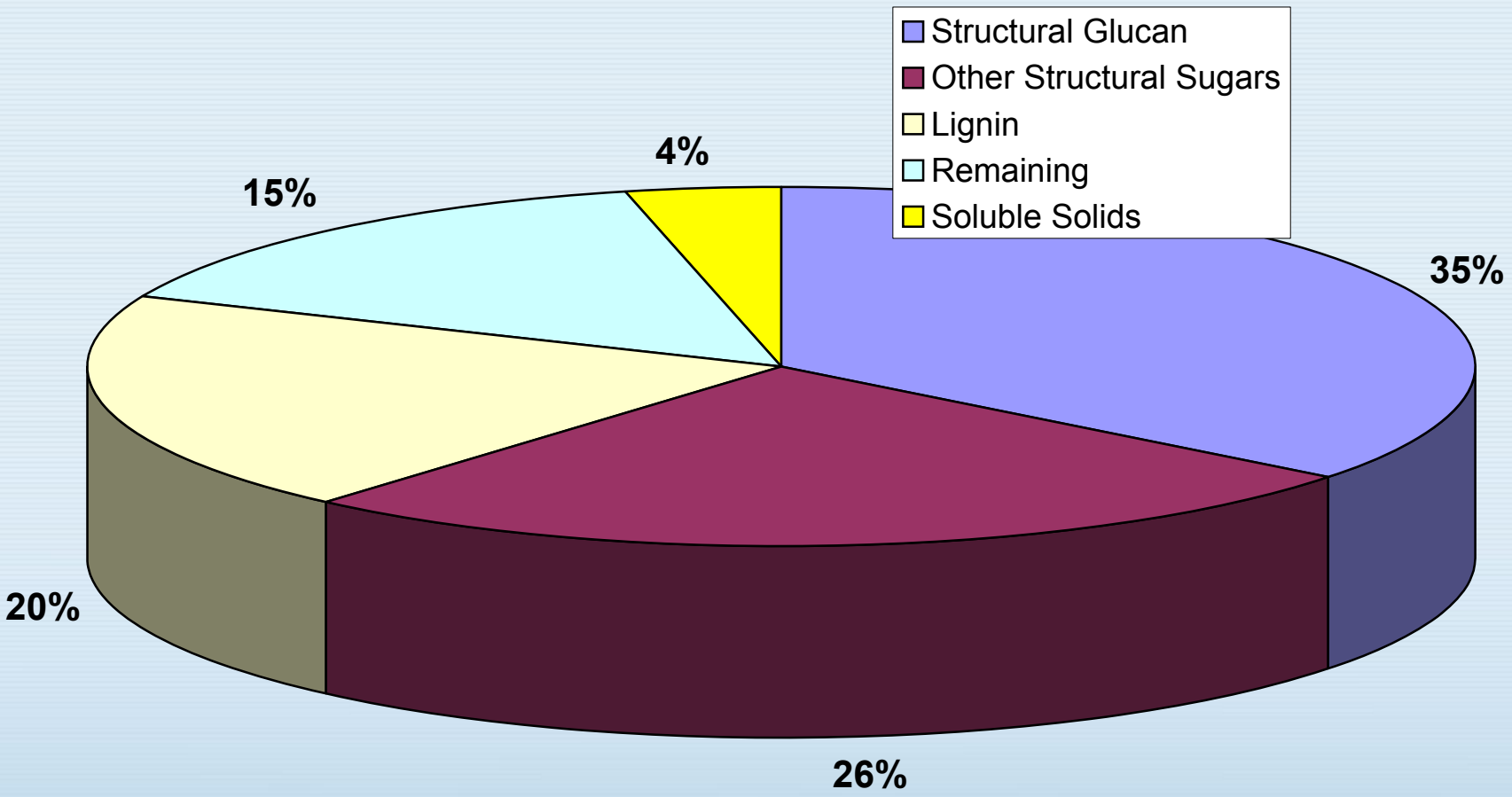
738 Samples

Feedstock Probability Functions

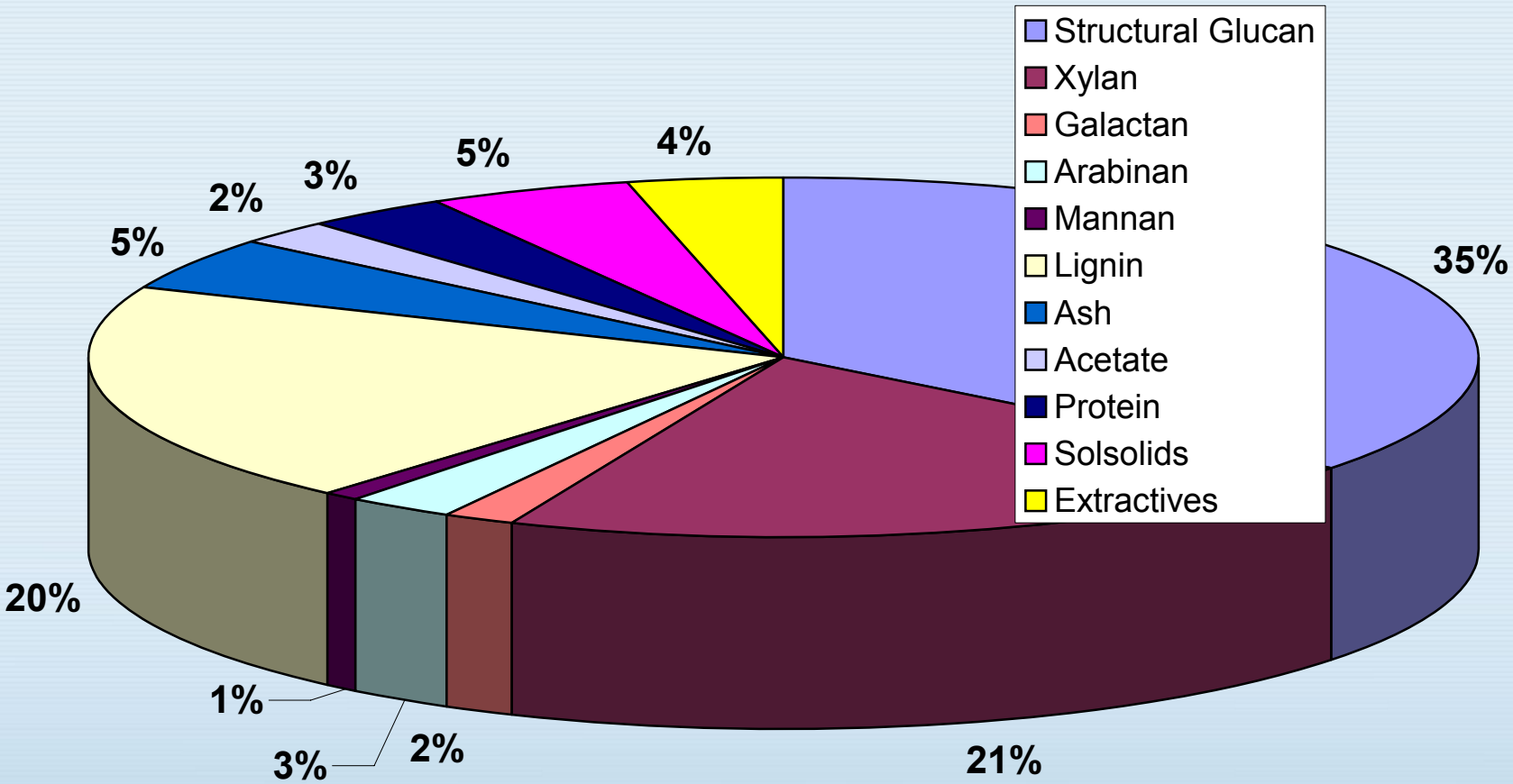
- Structural glucan
- Other structural sugars
- Xylan fraction of other structural sugars
- Lignin

- Constant ratios
  - Galactan/mannan/arabinan
  - Ash/acetate/protein/soluble solids

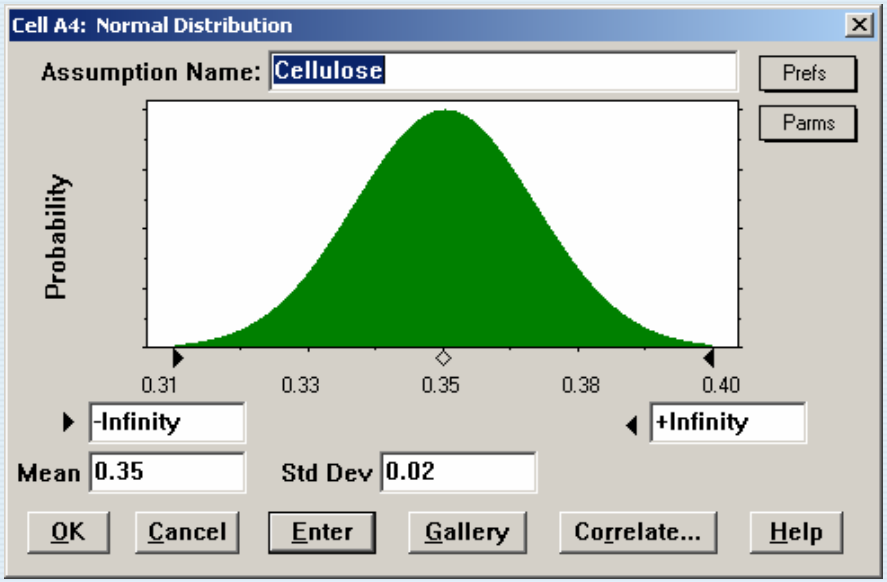
General Feedstock Composition

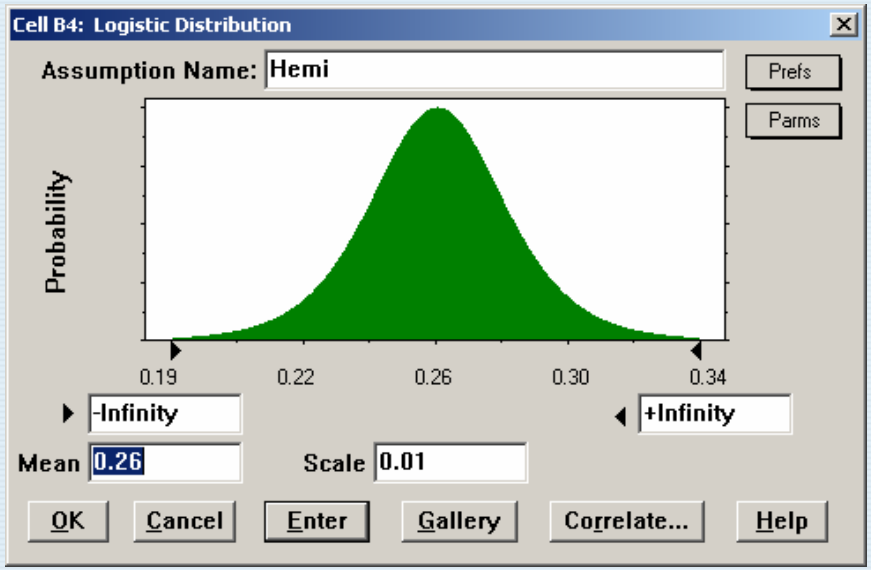


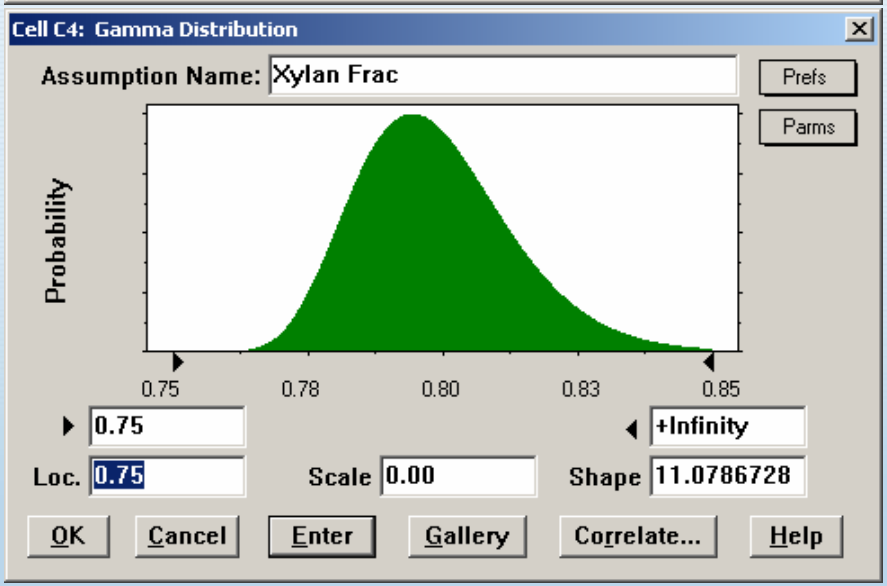
Component Breakdown

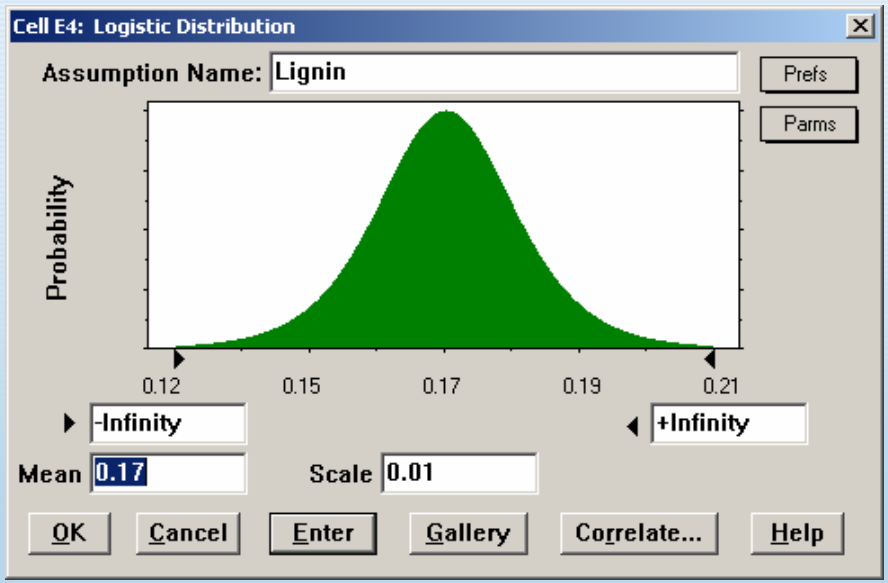


Feedstock Probability Distributions

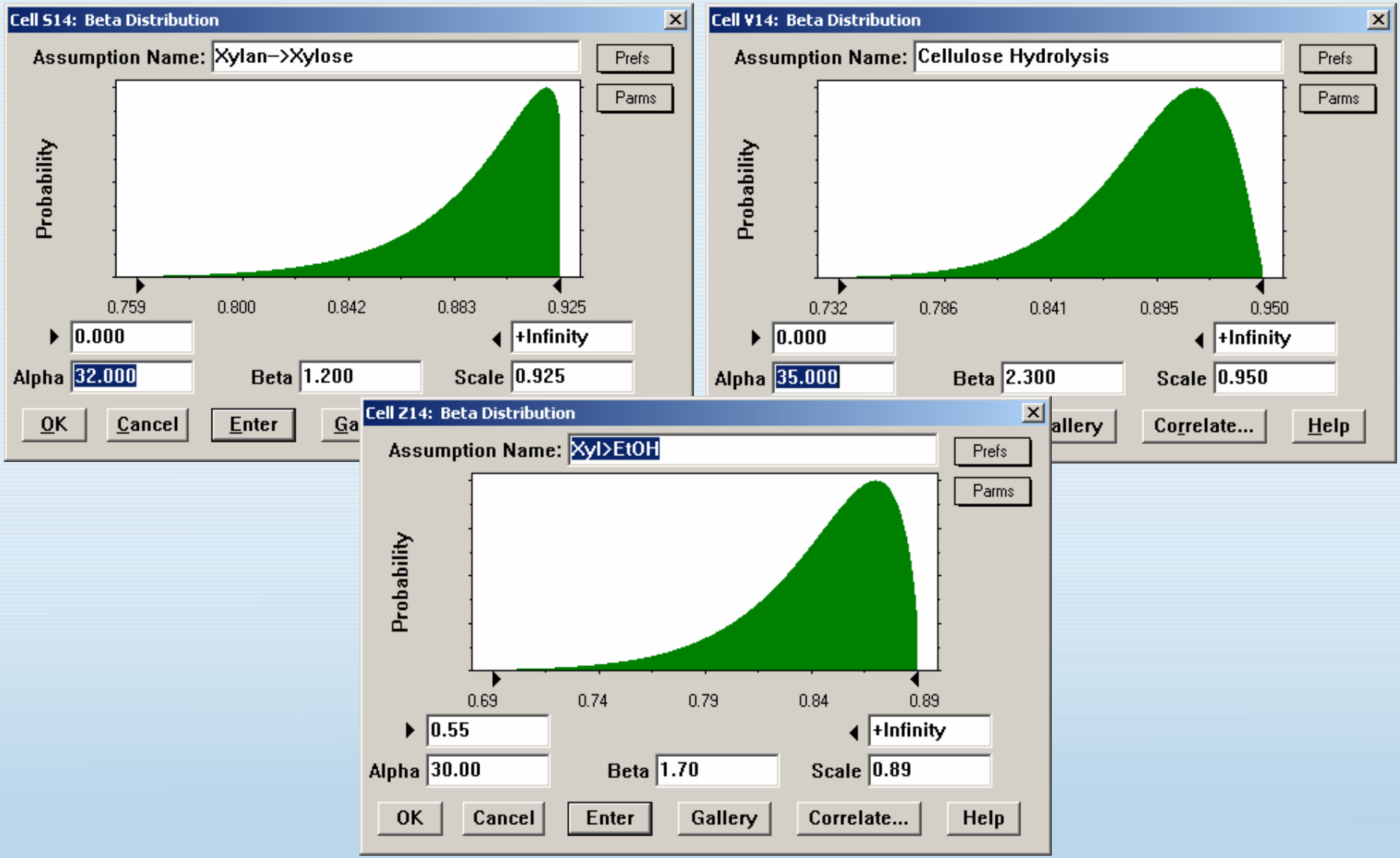




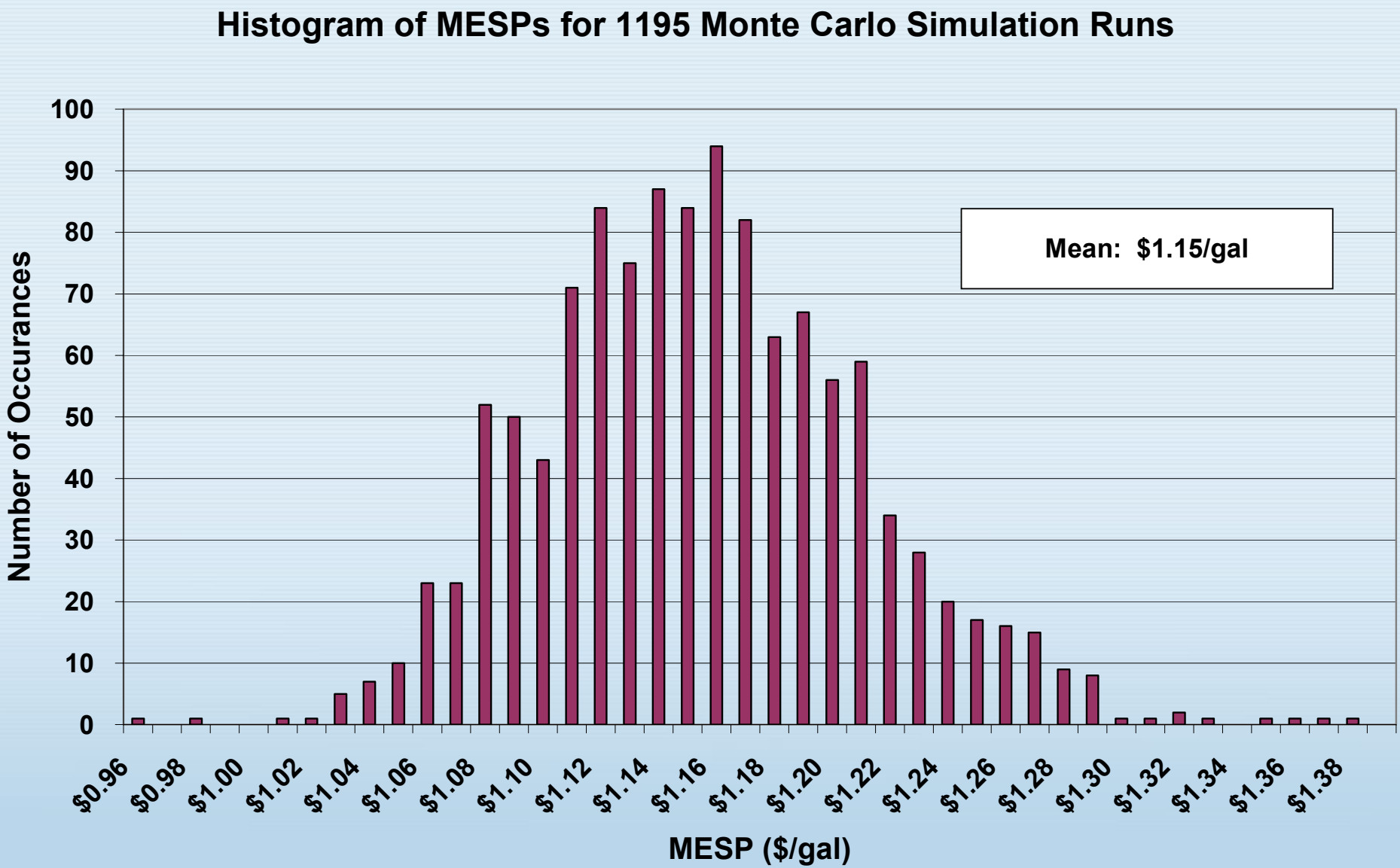




Yield Probability Distributions



Monte Carlo Analysis Results



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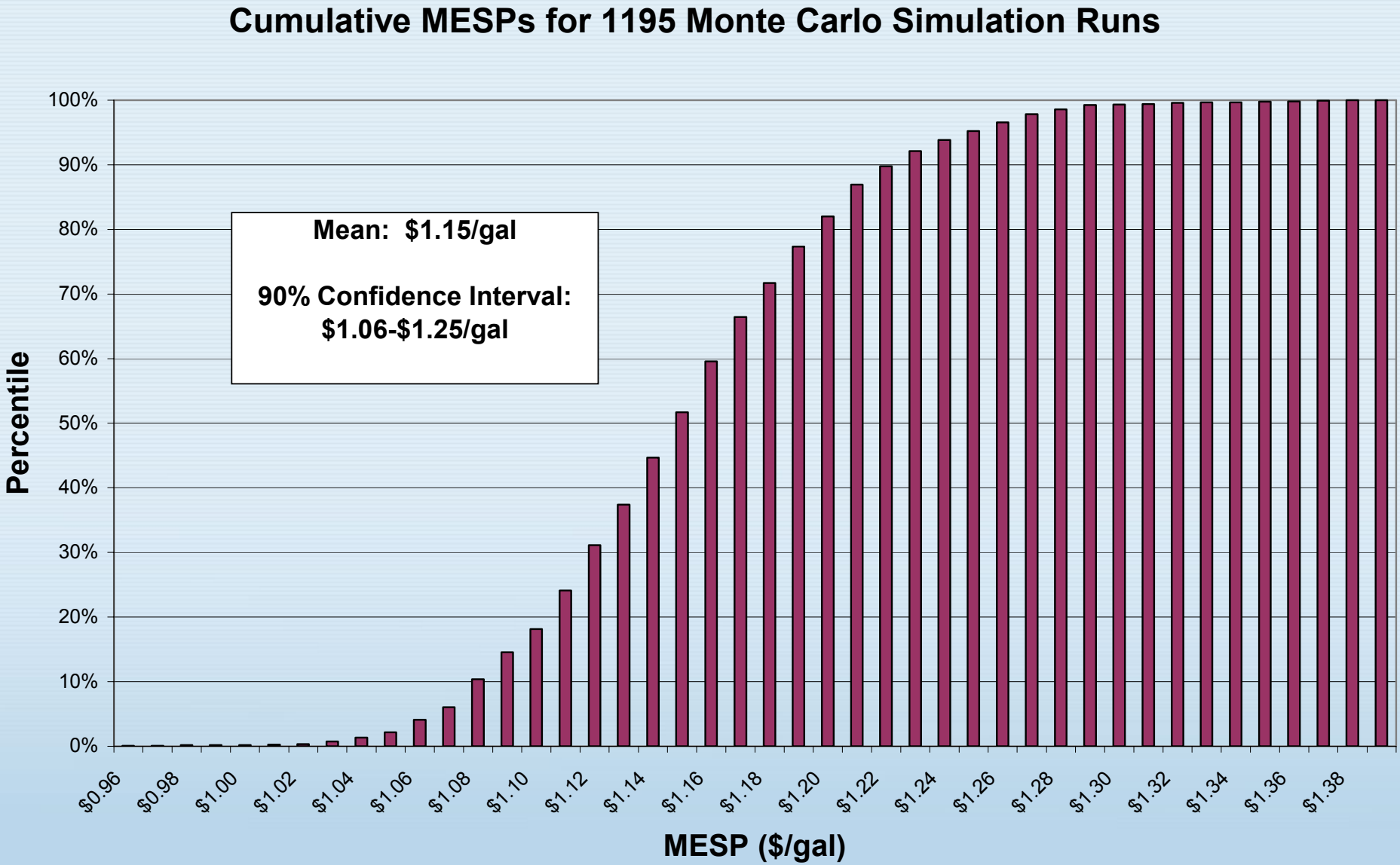

Conclusions

- Monte Carlo is useful for confidence interval estimates
  - A technique has been developed to use ASPEN batch techniques and Excel
  - Reams of data improve function definition but estimates can be useful
  - This analysis gave a 90% confidence interval of $1.06-$1.25/gal
- Monte Carlo can also be used to estimate design constraints

Acknowledgement

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