

# **Why Simulation is Important: An Engineer's Perspective**

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*Chris Koh is an employee of PepsiCo Inc. The views expressed in this presentation are those of the author and do not necessarily reflect the position or policy of PepsiCo, Inc.*

# Today's Agenda

**Simulation: Why and What?**

**Case Studies**

**Looking into the Future**

# '7 Minutes of Terror'

Curiosity Lands on Mars: Know What You're Watching When You're Watching '7 Minutes of Terror' -- Windows Internet Explorer

http://www.theatlantic.com/technology/archive/2012/08/curiosity-lands-on-mars-know-what-youre-watching-when-youre-watching-7-minutes-of-terror/260725/ the atlantic

File Edit View Favorites Tools Help

SSO Login Services Curiosity Lands on Mars: ... X

**The Atlantic**

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## Curiosity Lands on Mars: Know What You're Watching When You're Watching '7 Minutes of Terror'

MEGAN GARBBER | AUG 5 2012, 4:00 PM ET

1k 409 23 +1

A cheat-sheet guide to the dramatic descent of the Little Rover That Could



NASA

UPDATE August 6, 1:42am EDT: The Mars Curiosity rover has safely landed on the surface of Mars! See the scene at mission control when they got word. Spoiler alert! They were nuched.

VIDEO

What Straights Can Learn From Same-Sex Couples

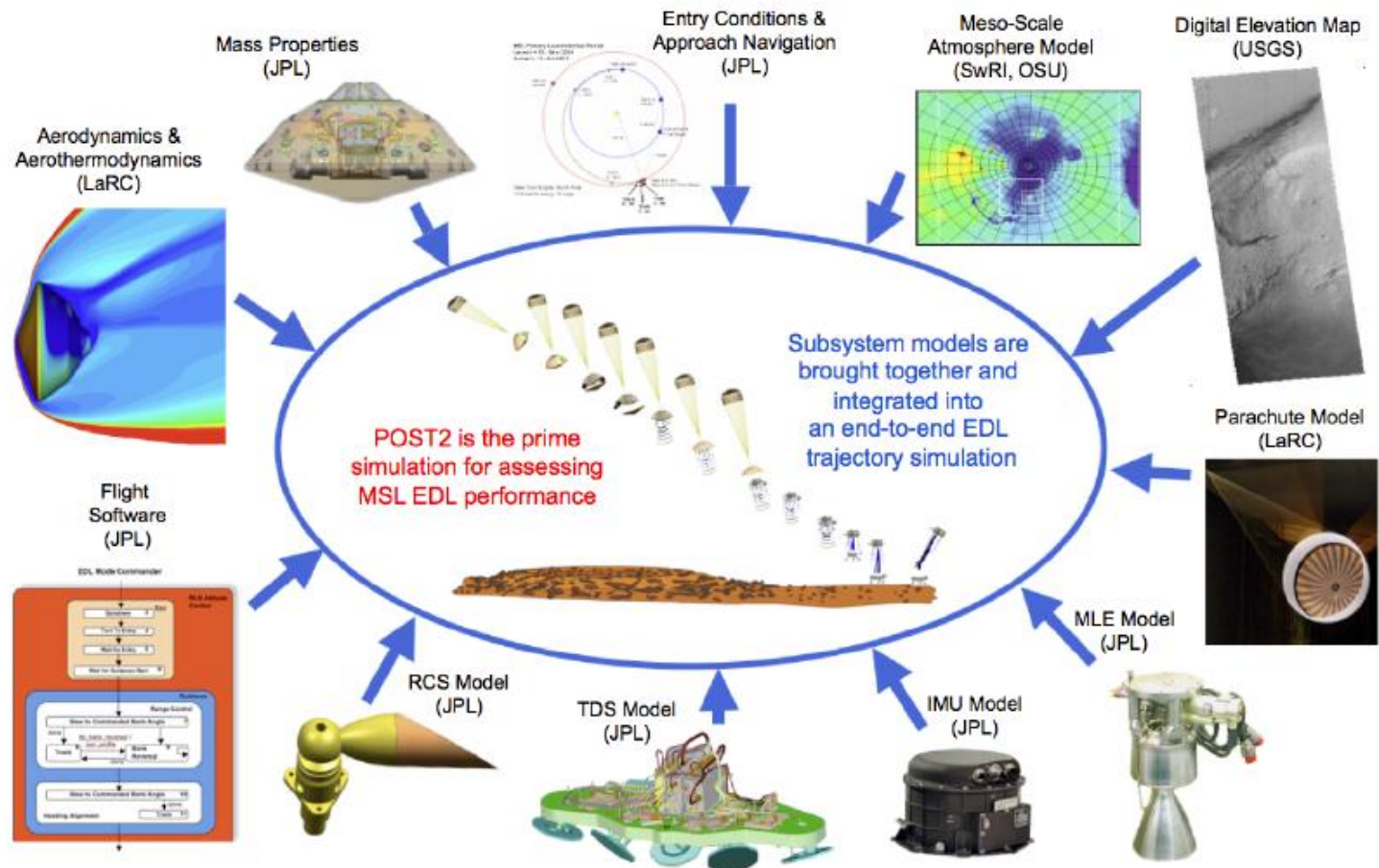
New insight from decades of research

See how businesses are transforming in the IBM SmartCloud.

Go now >

start Curiosity Lands on M... Microsoft Outlook Simex 2013 Keynote ... 12:15 PM

# Simulation helped land Curiosity in Mars



**Figure 1. MSL EDL POST2 simulation modeling.**

# Simulation

## Discipline

Meteorology

Economics

Mech. Eng.

Chem. Eng.

Chemistry

Atmos. Sci.

Model

Define scale and system

Monte Carlo  
Stochastic  
Finite Element

Cellular Automata  
Finite Difference  
Etc.

## Application

Weather  
Forecast

Stock  
Market

Automobile  
Design

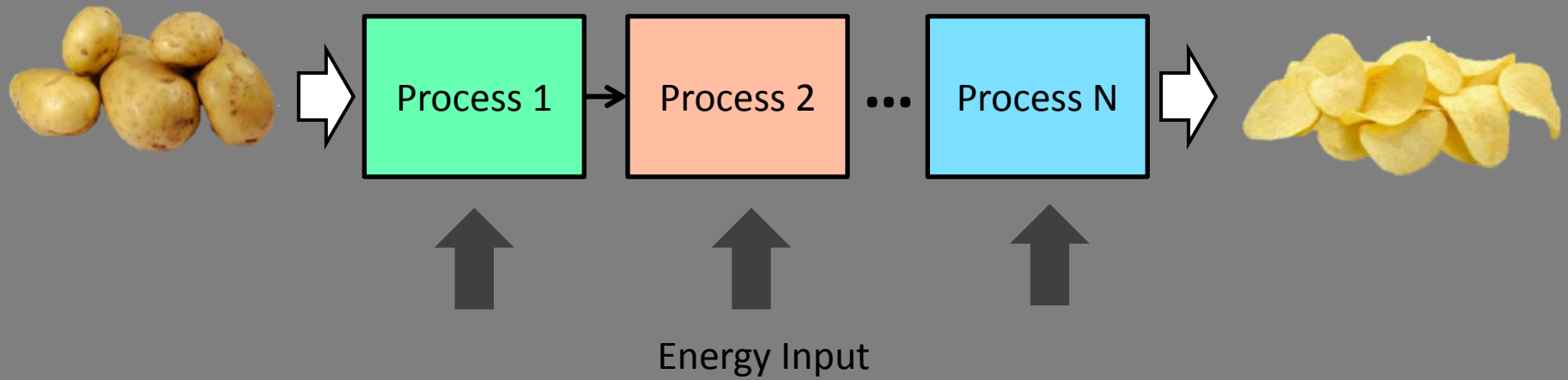
Chemical  
Processing

Refinery

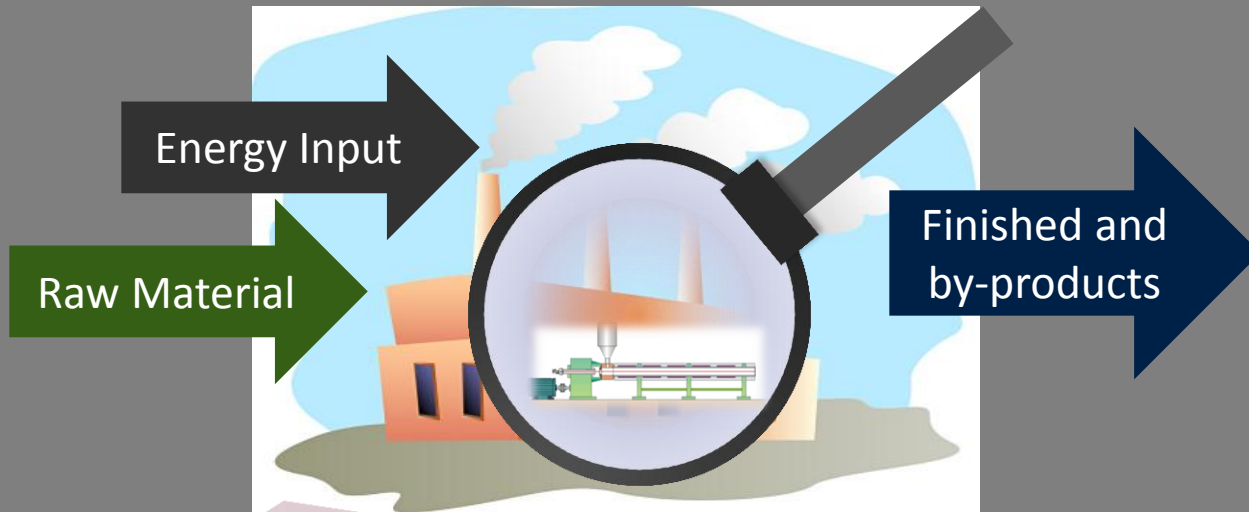
Pollution  
Study

Reality

# Process Engineering



# Factory Scale



## Typical Questions

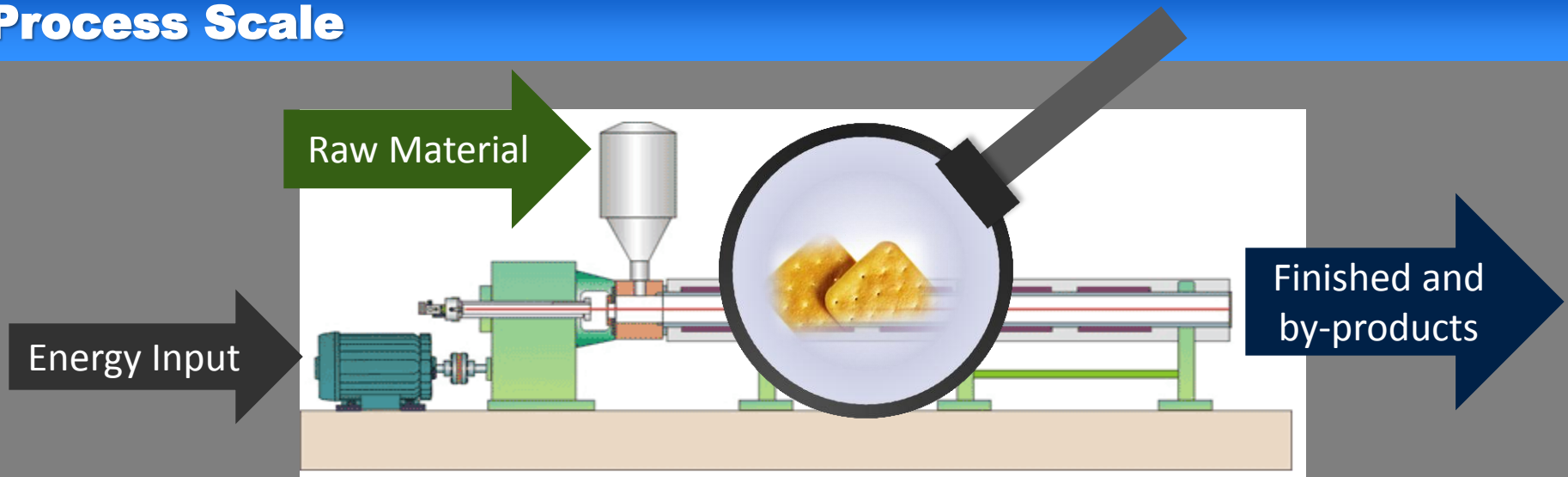
- Why is Line A's energy consumption higher than Line B last Quarter ?
- Where is the bottleneck to throughput?

## Model Basis

- Heat balance
- Mass balance



# Process Scale



## Typical Questions

- How uniform is the temperature within the unit?
- What is the ramp-up time to reach steady-state?

## Model Basis

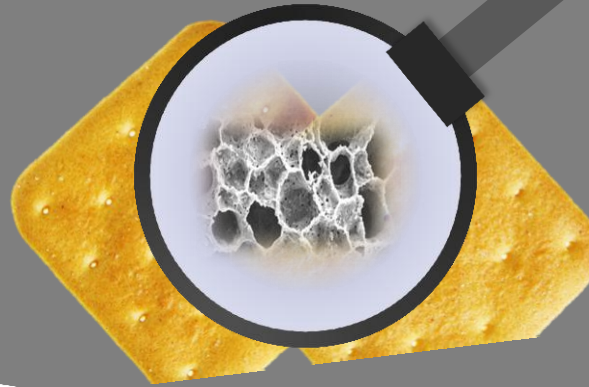
- Heat/Mass balance
- Heat/Mass/Momentum transfer
- Electro-Magnetism



# Piece Scale

54% corn meal, 31% oil, 14% water, 1% salt

Energy Input



64% corn meal, 33% oil, 2% water, 1.3% salt

Typical Questions

- What is the finished moisture?
- How uniform is the product stream? How uniform is each piece?

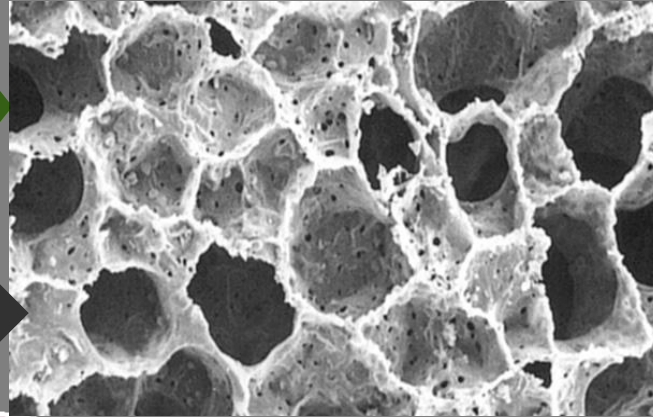
Model Basis

- Heat/Mass balance
- Heat/Mass/Momentum transfer
- Electro-Magnetism

# Micro scale

54% corn meal, 31%  
oil, 14% water, 1% salt  
Compounds A+B

Energy Input



64% corn meal, 33%  
oil, 2% water, 1.3% salt  
Compound C

Typical  
Questions

- What compounds are generated/destroyed?
- What does the microstructure look like (texture)?

Model Basis

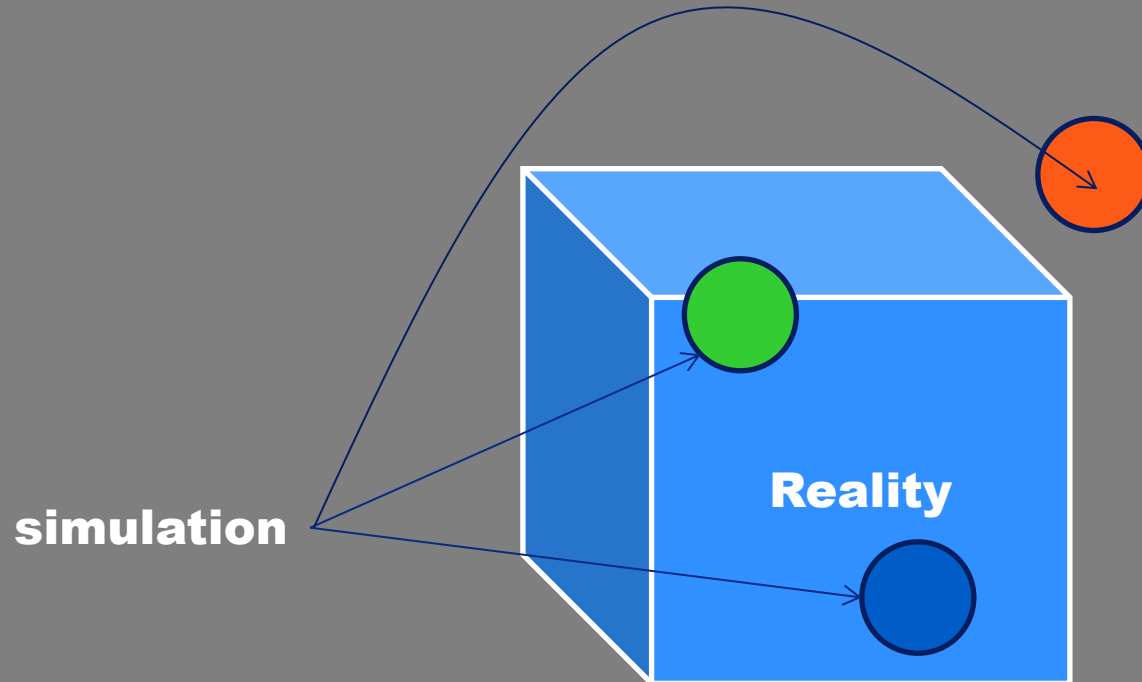
- Heat/Mass/Momentum transfer
- EM; reaction kinetics
- Constitutive equations gets complicated

# Why Simulation?



Source: [www.springfiles.com](http://www.springfiles.com)

# For an engineer...



## Benefits

- **Confirm view of reality**

- **Faster**
- **Cheaper**
- **Better**

- **Do the “impossible” experiment**

 **nice**    **useful**    **transformational**

# Today's Agenda

**Simulation: Why and What?**

**Case Studies**

**Looking into the Future**

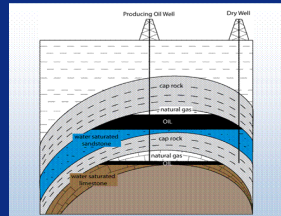
# Case Study I – Process Research

# Flow in Porous Media



## Diapers

Source: [homehealthdelivery.com](http://homehealthdelivery.com)



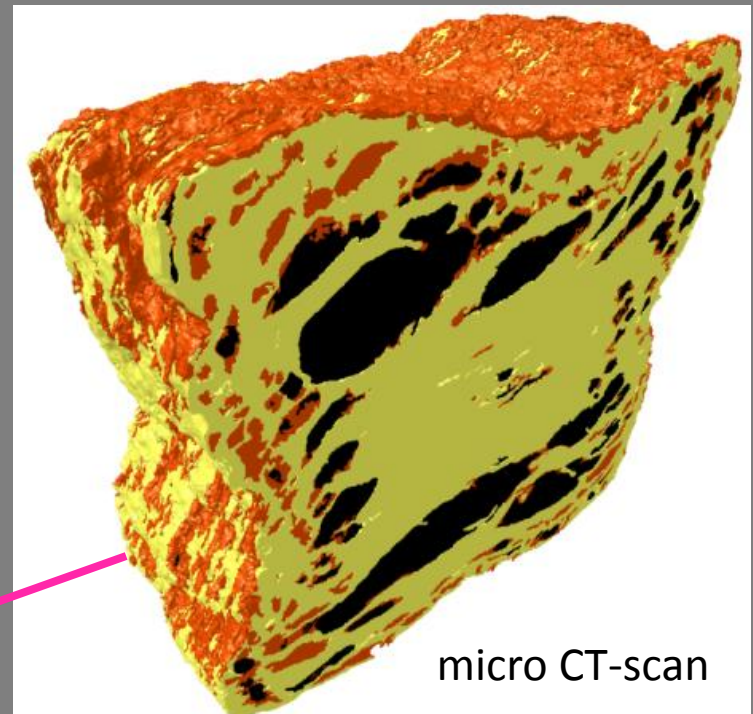
## Oil Reservoir

Source: [www.ems.psu.edu](http://www.ems.psu.edu)



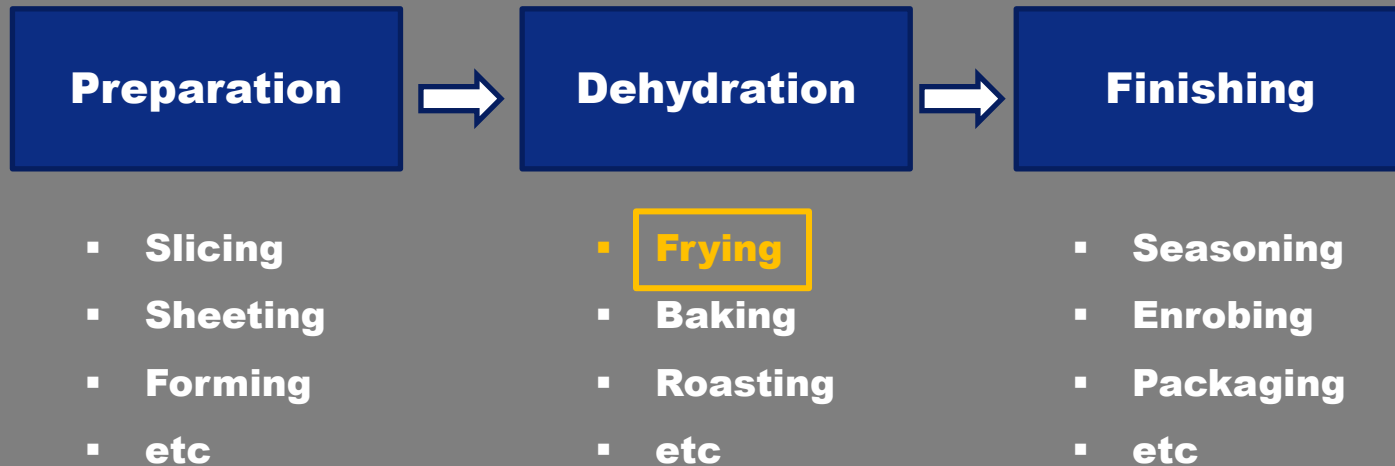
## French Fries

Source: [videojug.com](http://videojug.com)



micro CT-scan

# Frying



## Key function of frying

- Dehydration
- Flavor generation
- Color generation

## Key fryer requirement

- Consistent frying time
- Consistent frying temperature
- Maintain quality of oil



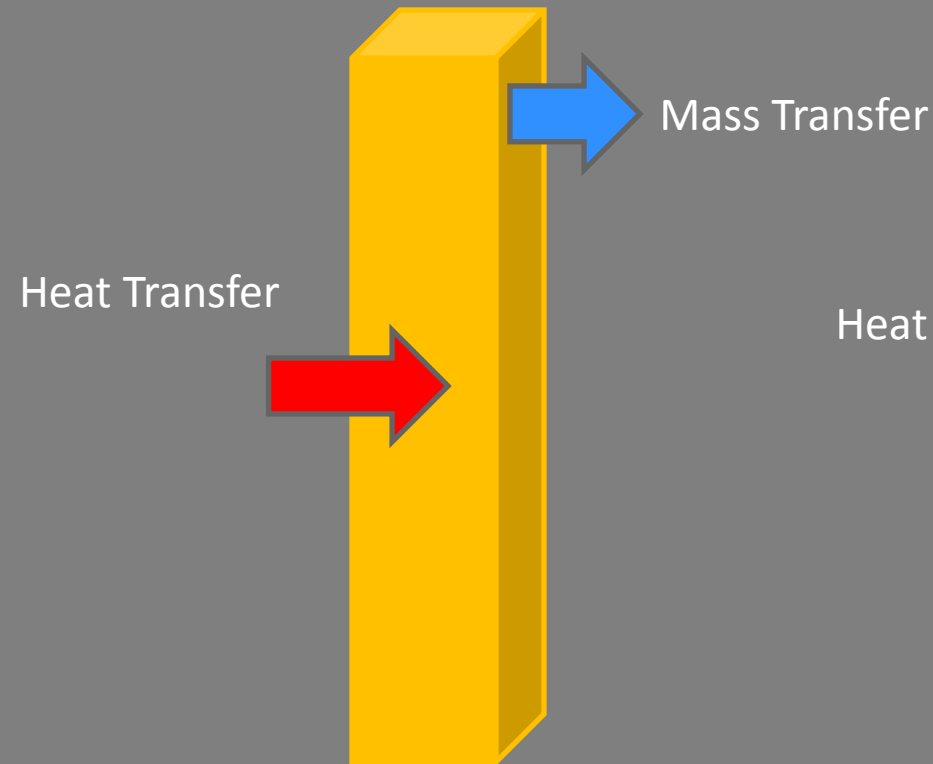
# Research Background

- Motivation
  - Health and wellness
  - Sensory impact
- Simulation to link process with product characteristics

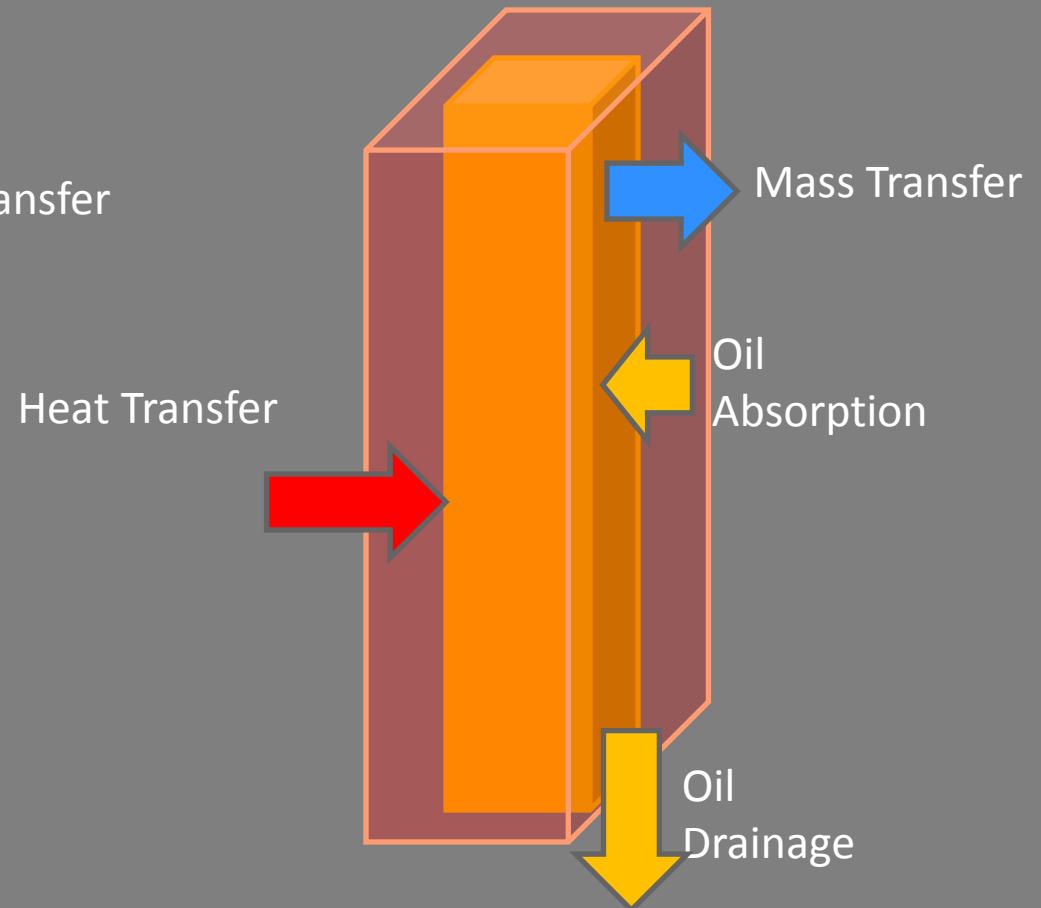
# Physics of Frying French Fries

**Goal: simulate heat/mass transfer and oil absorption/drainage**

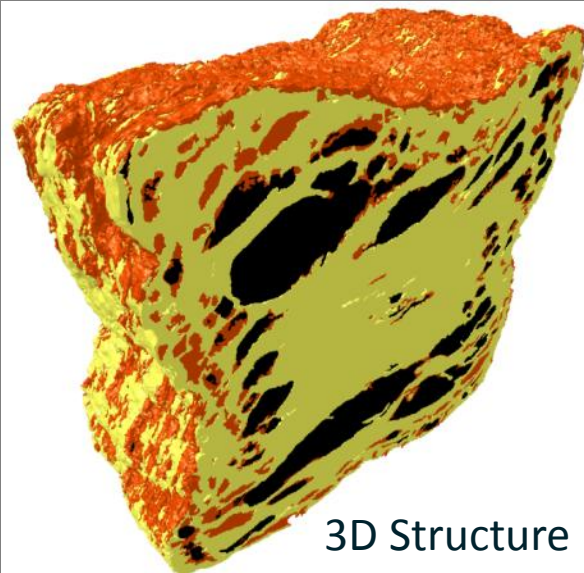
## During Frying



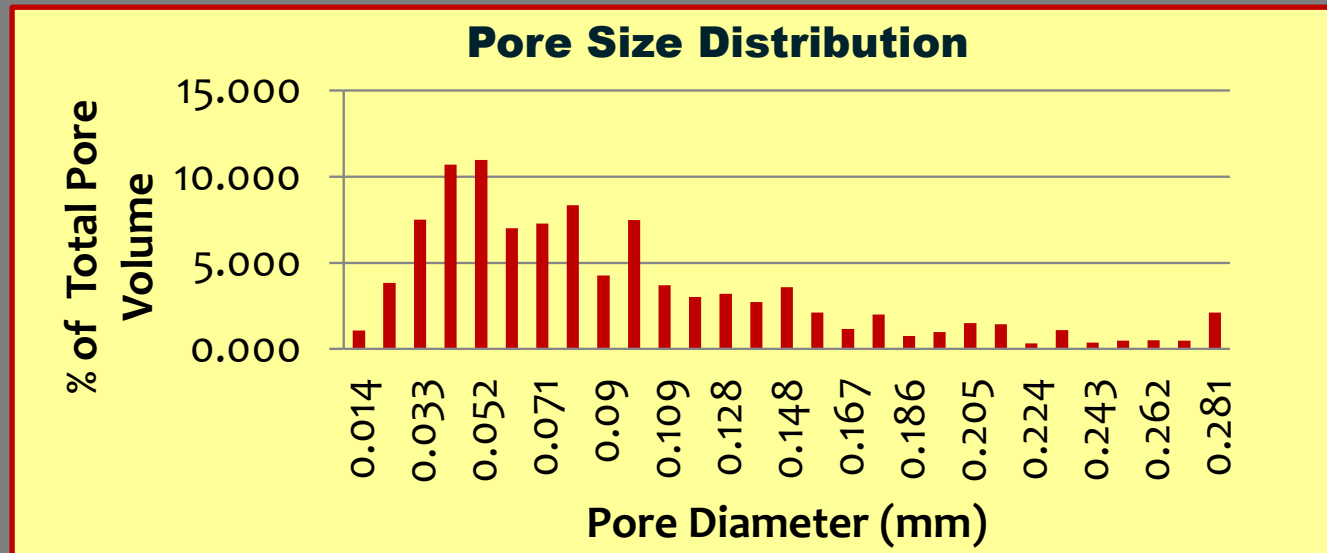
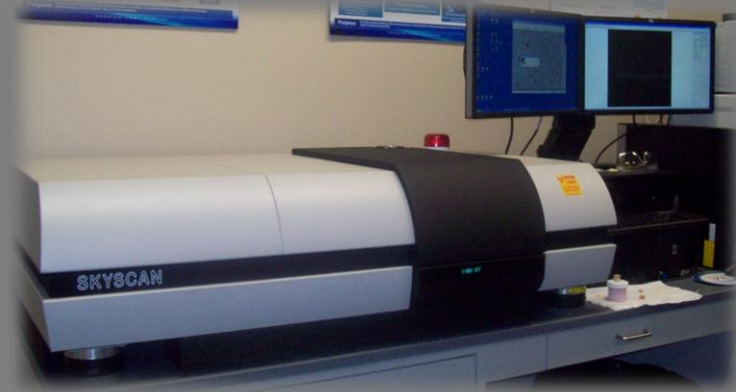
## After Frying



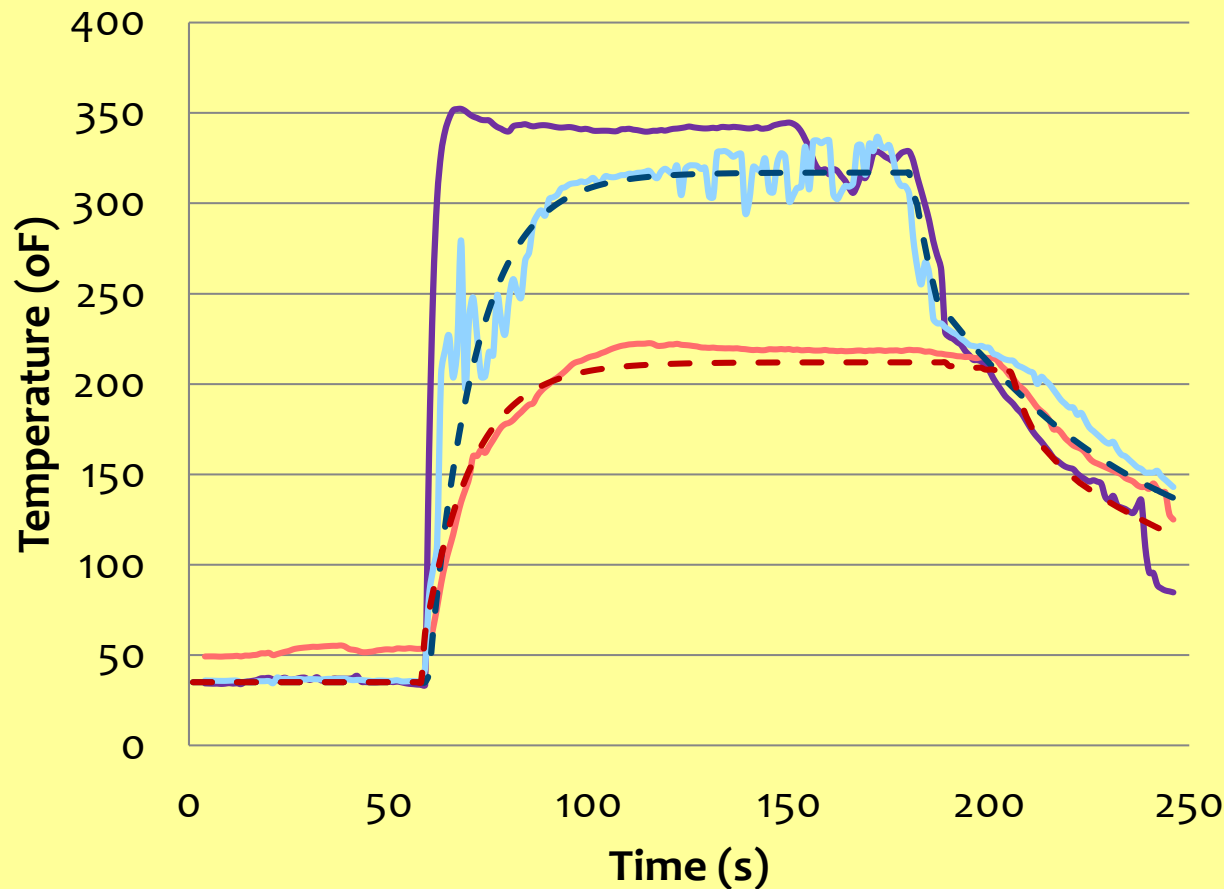
# Micro CT Scan of French Fries



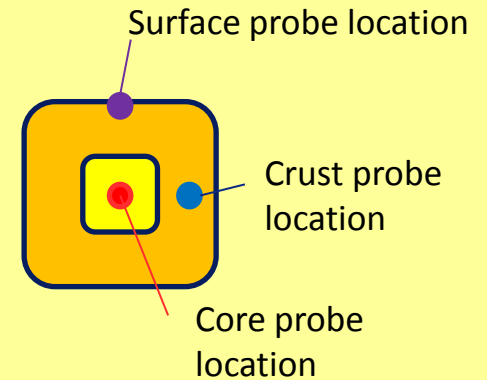
3D Structure



# Validation of Temperature Prediction



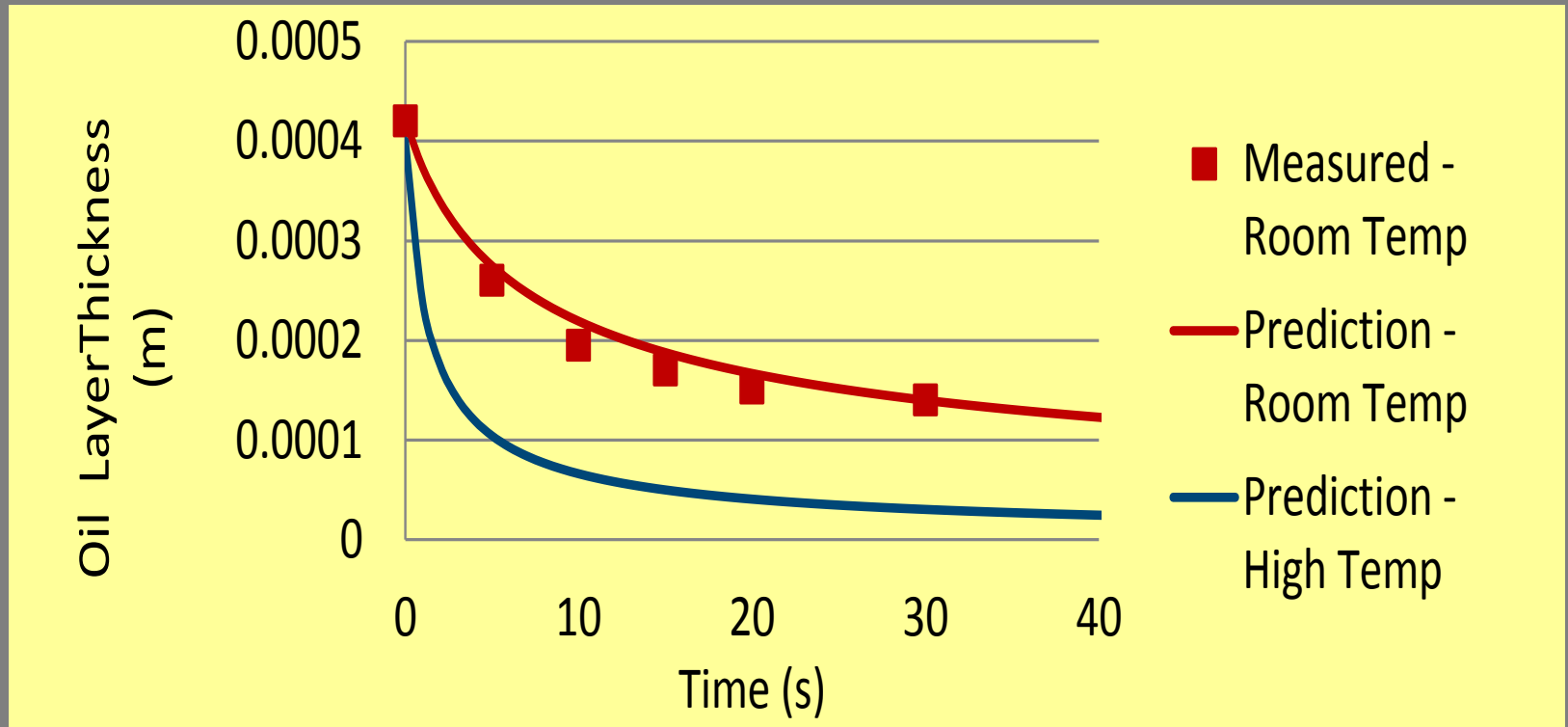
## Locations of Temperature Measurements



- Measured Surface Temp
- Measured Core Temp
- Measured Crust Temp
- - Predicted Crust Temp
- - Predicted Core Temp

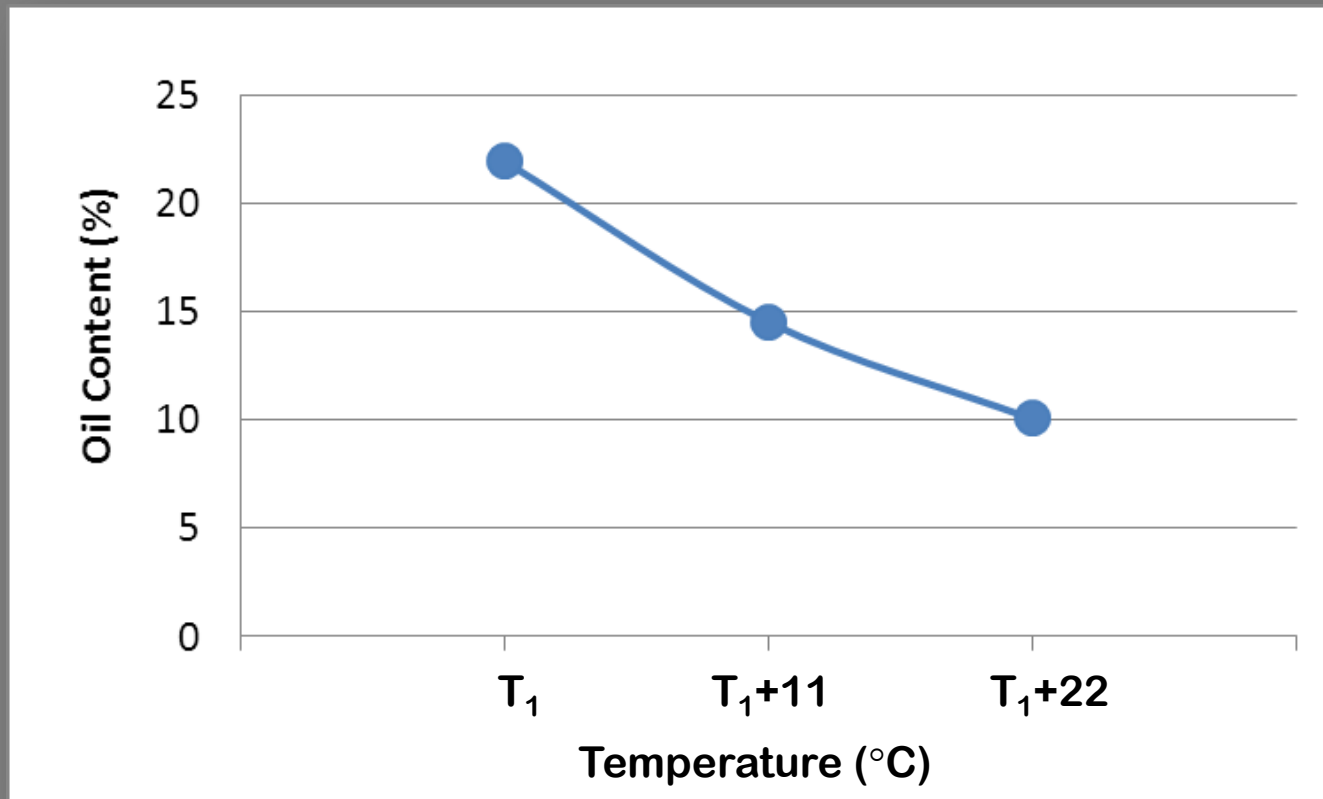
**Good agreement between experimental THERMAL data and simulation**

# Validation of Oil Drainage Predictions



**Good agreement between experimental DRAINAGE data and simulation**

# Impact of Frying Temperature



# **Case Study I summary**

- **Gain insight on french fries processing**
  - **Frying temperature can impact oil content**
  - **Small window of opportunity after frying**
- **Can translate model to other food products**



# Key Steps of Simulation

**Define scale & system**  
**Define simulation goals**

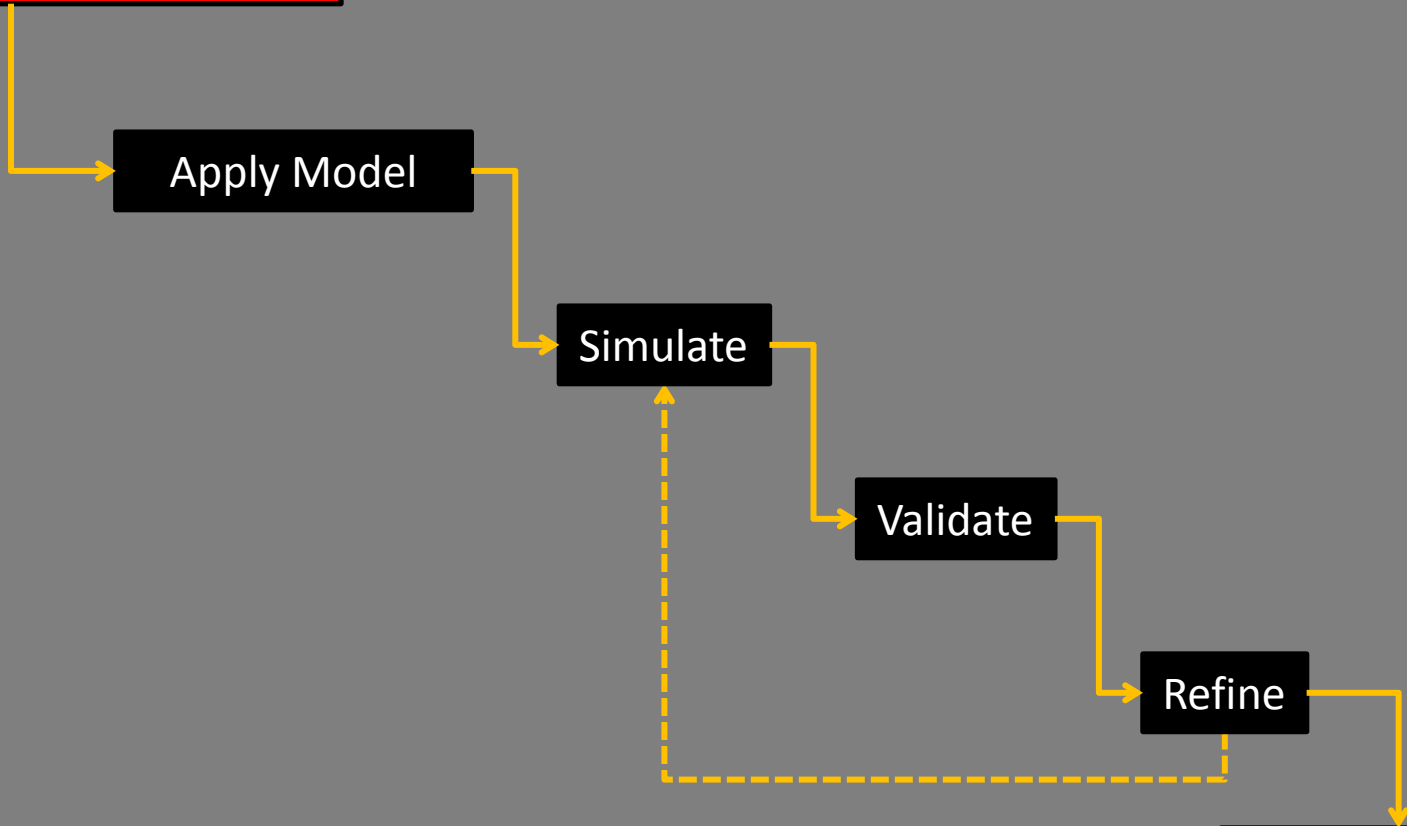
Apply Model

Simulate

Validate

Refine

**Use Results**

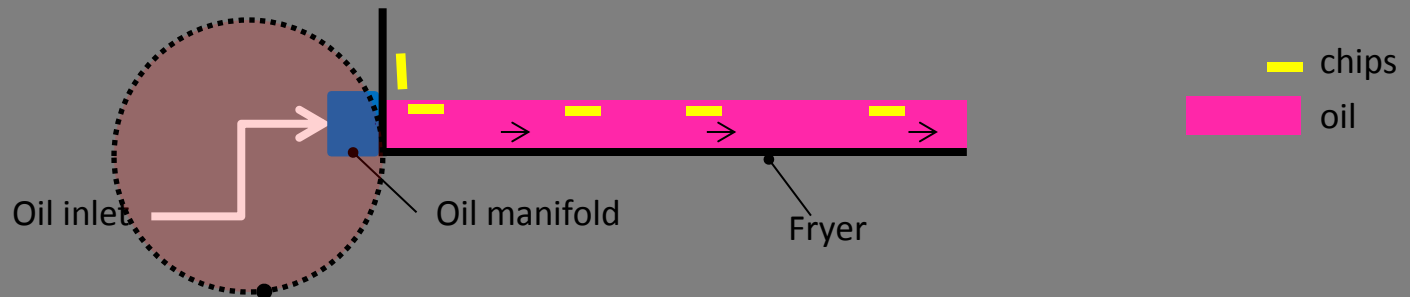


# Case Study II – Equipment Prototyping

**Problem: Design a brand new fryer**

**Challenge: Consistent frying duration**

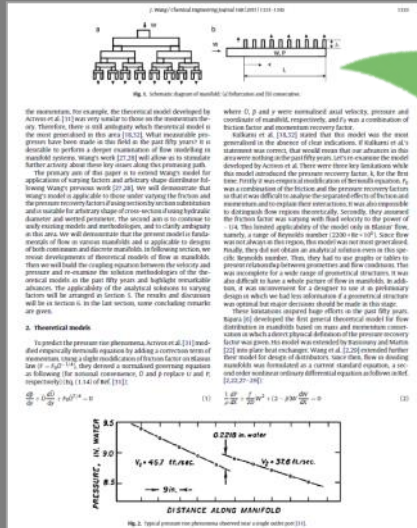
Side view of conceptual fryer



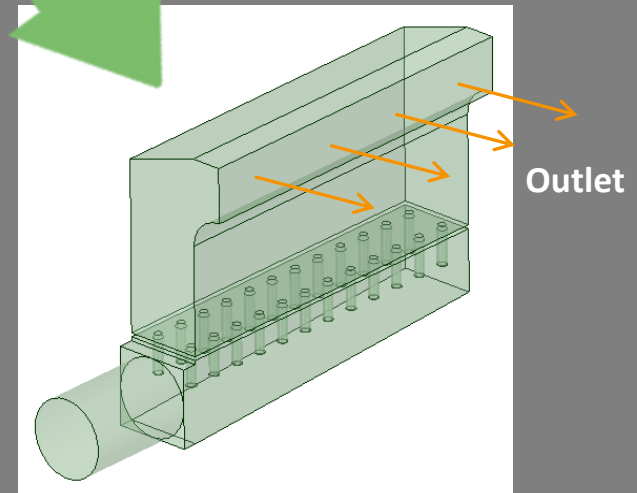
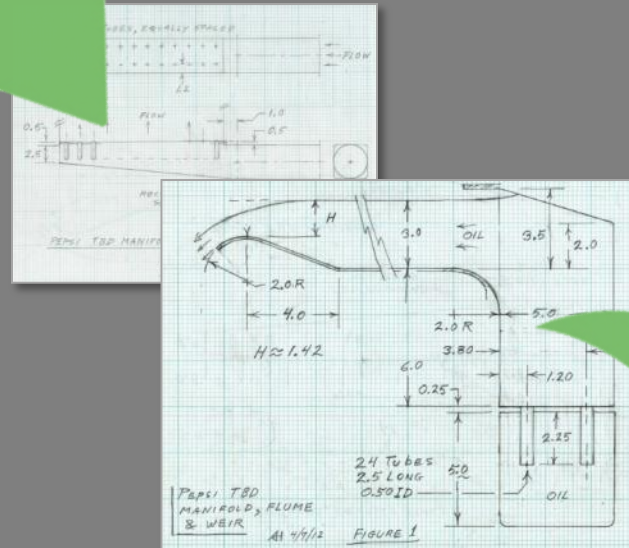
Simulate this:

- Scale: Process scale simulation
- System: pipes and manifold
- Goal: Uniform flow

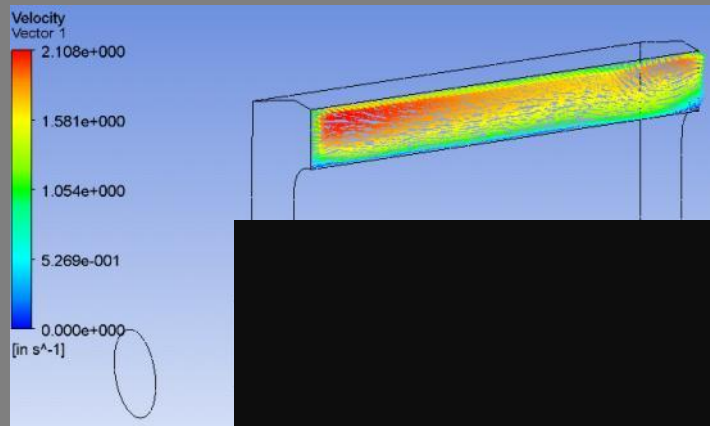
# Where do we start?



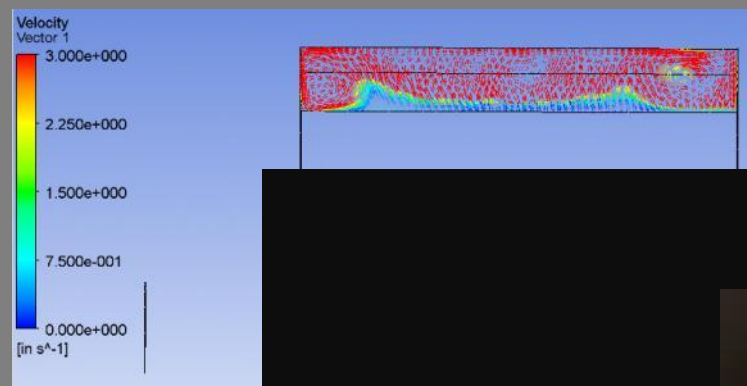
J. Wang, Chemical Engineering Journal, 168 (2011) 1331-1345



# Iteration No. 1



# Iteration No. 2



# Impact

	Trial and Error (Estimate)	With Simulation	Direct Benefit
Prototype and Testing Cost	US\$ 50K x 10 = <b>US\$ 500K</b>	US \$50K x 2= <b>US\$ 100K</b>	Cost Savings = <b>US\$ 400K</b>
Prototype and Testing Time	5 weeks x 10 = <b>1 year</b>	5 weeks x 2 = <b>2 month</b>	Time Savings = <b>10 months</b>

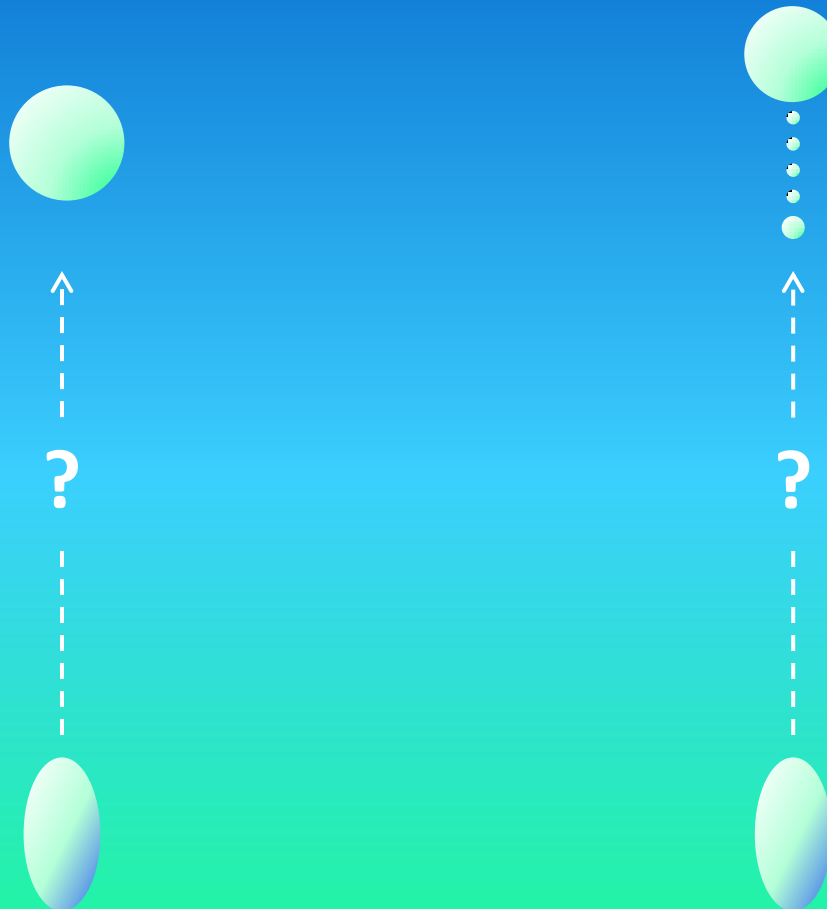
*For illustration purpose, not actual investment*

## Indirect Benefit

- **Better solution**
- **Confidence with management and business partners**
- **Faster to market**

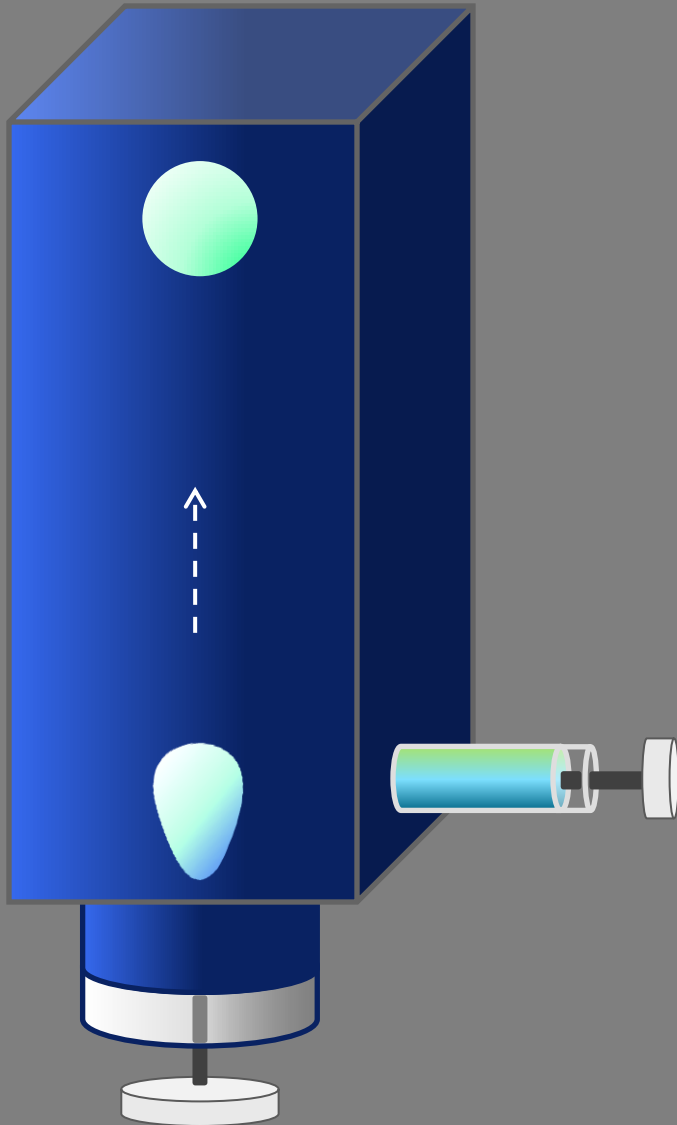
# Case Study III – Fundamental Research

1986

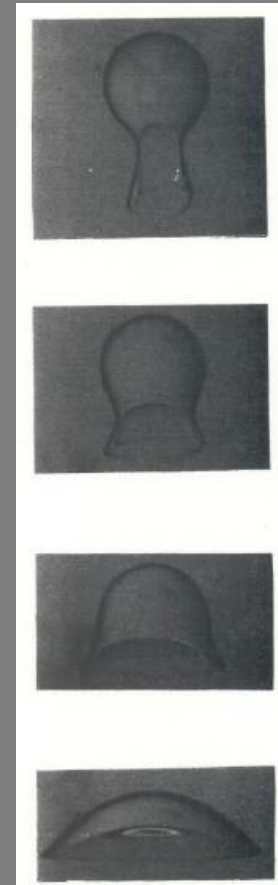




# Experimental Approach



Prolate



Oblate

# Simulation Approach

## Fluid Mechanics Model

$$0 = -\nabla p_1 + \nabla^2 u_1$$

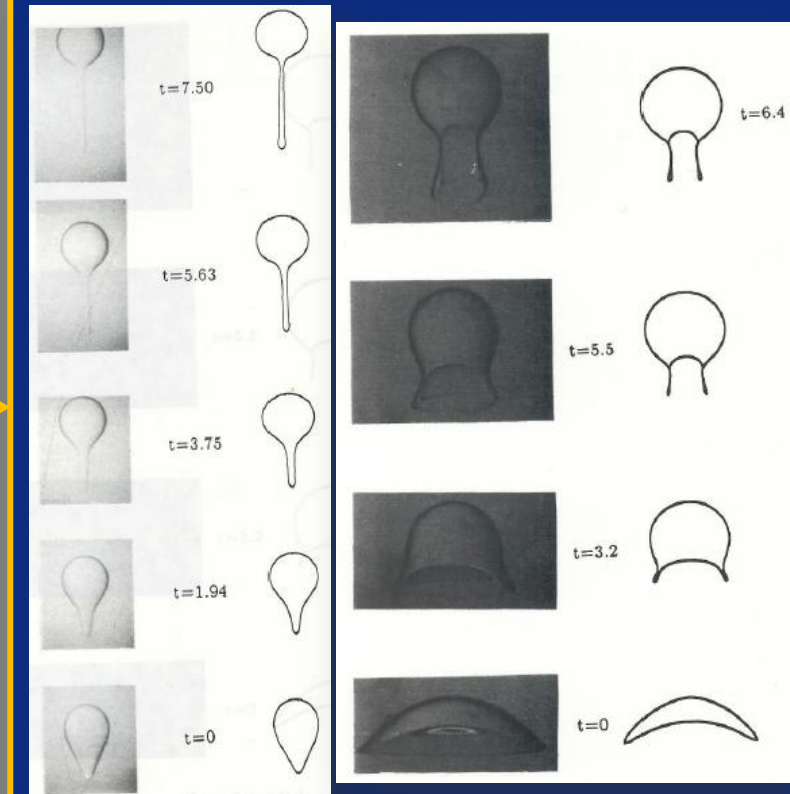
$$0 = -\nabla p_2 + \nabla^2 u_2$$

$$u_2 \rightarrow 0 \text{ as } \|x\| \rightarrow \infty$$

$$u_1 = u_2 \text{ at interface}$$

$$\lambda \mathbf{n} \cdot \mathbf{T}_1 - \lambda \mathbf{n} \cdot \mathbf{T}_2 = -\frac{\mathbf{n}}{\text{Ca}} \nabla \cdot \mathbf{n} - \mathbf{n} z \frac{3(1 + \frac{3}{2\lambda})}{1 + \lambda} \text{ at interface}$$

**Boundary Integral Technique**  
(implemented numerically)



# Impact



# Today's Agenda

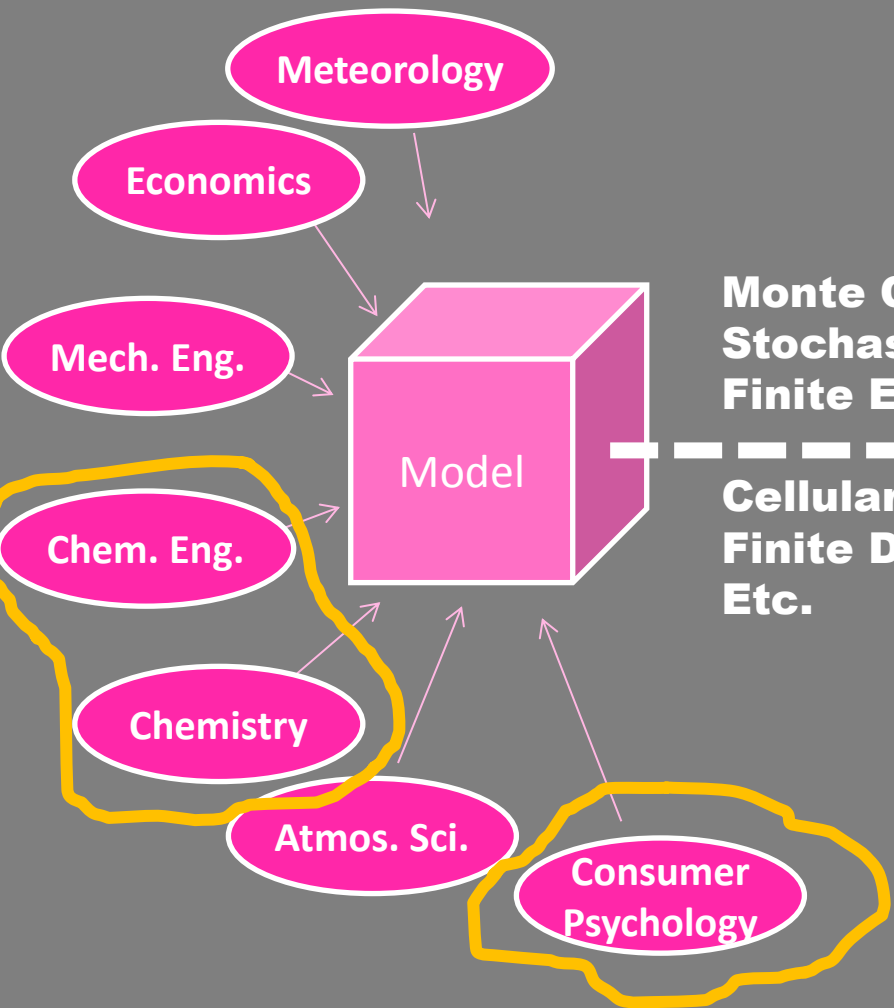
**Simulation: Why and What?**

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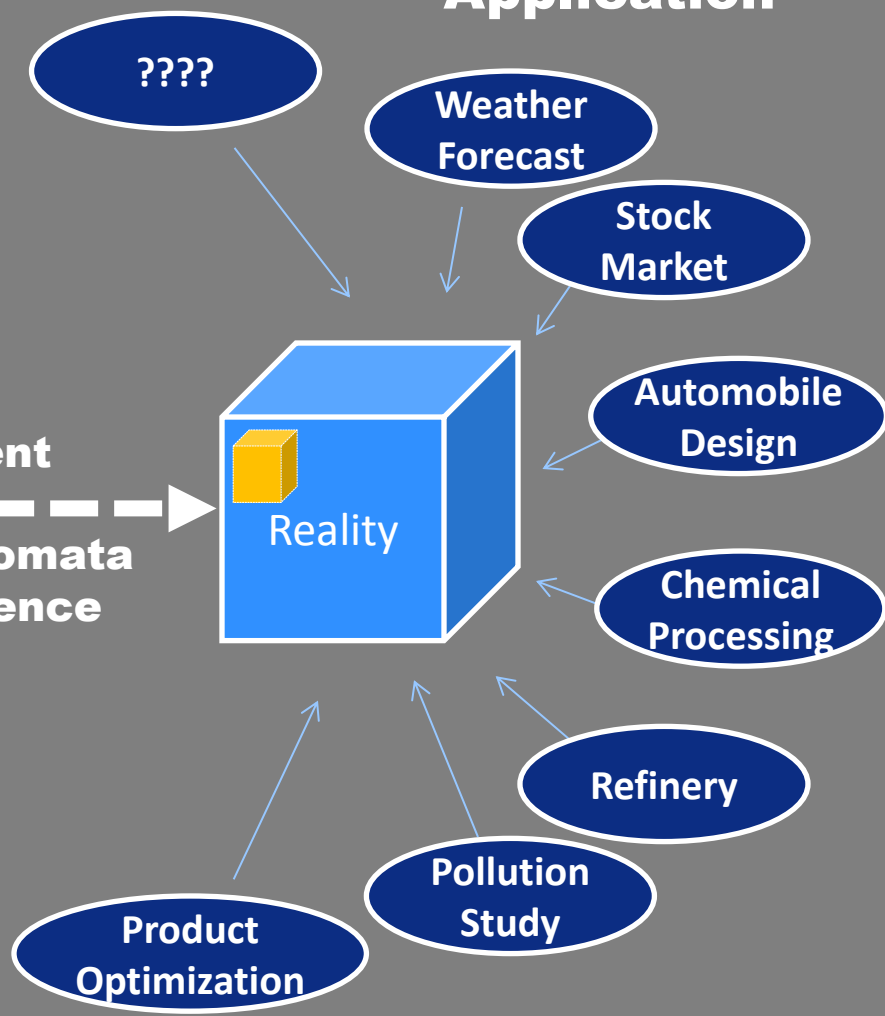
# Future

## Discipline



Monte Carlo  
Stochastic  
Finite Element  
Cellular Automata  
Finite Difference  
Etc.

## Application



# Acknowledgment

**Sean Eichenlaub, PhD, PepsiCo Advanced Research**

**Dagbjørn Skipnes, PhD, Nofima**

**PepsiCo Global R&D Fellows Program**





# and finally...

Start with what you know

Just because you can, doesn't mean you should

Assumptions...make them, but beware

Quality in, quality out

It's "virtual reality," so don't forget the reality

# THANK YOU!