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## DOE for World-Scale Manufacturing Processes: Can We Do Better?

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## DISCLAIMER

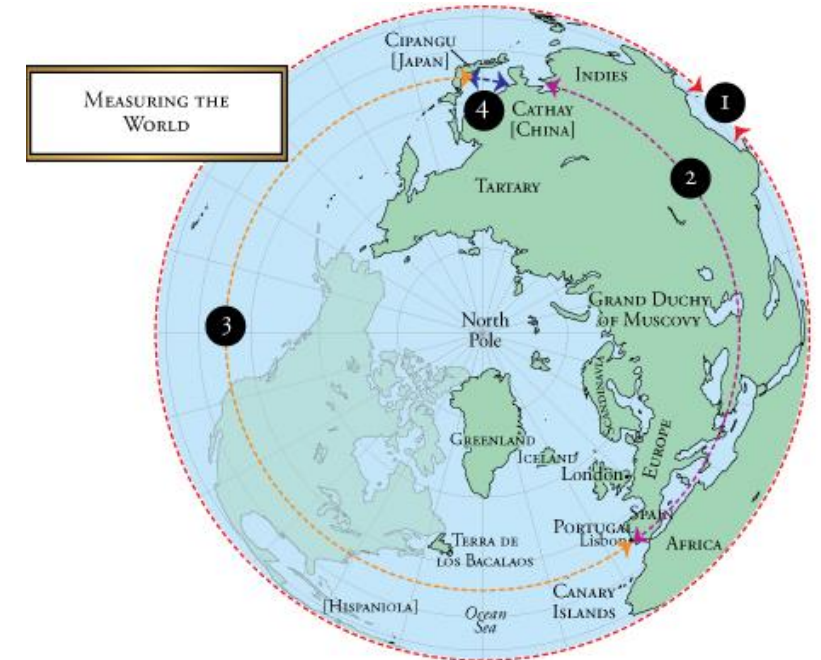
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# Age of Exploration – The Columbus DOE

- Columbus set sail for India in 1492 on the wrong hypothesis that the Earth's circumference was 25% smaller than reality (1).
- This triggered a series of wrong assumptions (2,4).
- Which in turn made him believe he could reach Japan (3) by sailing only 3200 miles (real distance 11000miles).
- Without these wrong assumptions and calculations he would have never set sail westward.
- This was the basis on which he could get the budget to start one of the most expensive experiments in history.



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

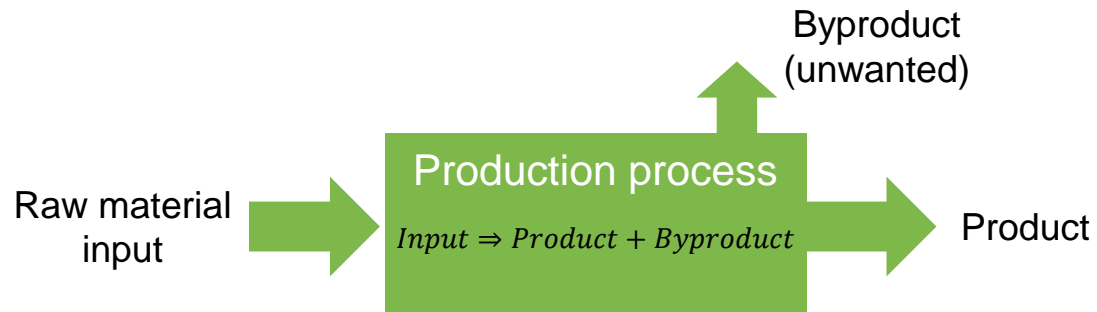
# Age of Exploration – DOE in world-scale manufacturing processes

- Columbus was a self-taught man, same is true for most of engineers dealing with statistics and DOE
- Content of the presentation:
  - ▶ What is a world-scale manufacturing process?
  - ▶ What are the challenges when applying statistics?
  - ▶ How can we define a DOE on such a process?
  - ▶ Can we do better?
- Trigger a new “Age of Exploration” for DOE in process industry



# World-scale manufacturing processes

- Very large continuous production process → 1000+ton/day
- High raw material cost
- Production of unwanted byproducts reduces process yield
- Process yield varies over time
- Large number of unmeasured or unmeasurable variables



*Yield* *Y*

*Product* *X*

*Conversion* *X*

*Ratio* *X*



Illustrative picture of continuous production plant in BASF Antwerp

# Challenges in DOE

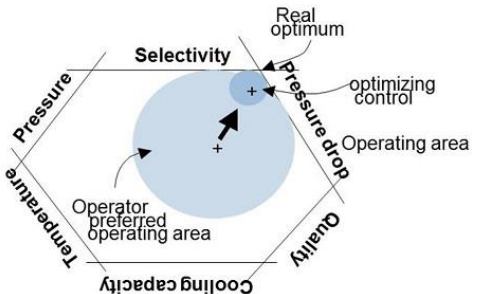
- A manufacturing plant is not a lab
- 5-10 parameters of interest
- Low signal to noise ratios
  
- One experiment takes up to 1 week, and costs a lot of money
- Experimental budget is limited to 5-10 experiments
  
- Safety, environmental and quality constraints



VS



There's Just Not  
**ENOUGH**  
*Time!*



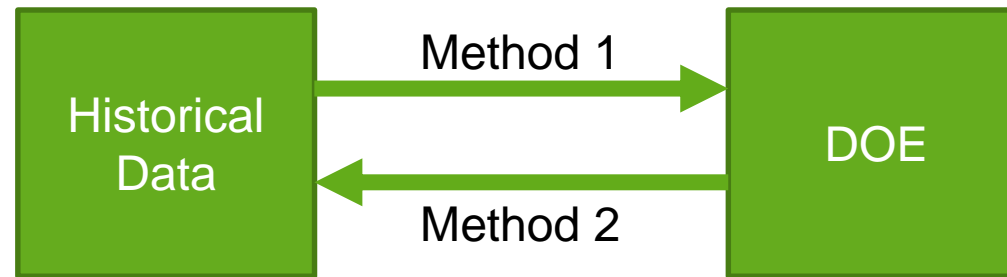
# “Standard” DOE solutions are not optimal

- One factor at the time (OFAT):
  - ▶ very inefficient, too time consuming
  - ▶ cannot detect interactions
  - ▶ still very common in process industry...
- Classical and even advanced DOE methods (definitive screening design, custom design):
  - ▶ might still require too many experiments, too costly
  - ▶ can be difficult to justify
  - ▶ do not leverage what we already know



# How can we define a cost-effective DOE on such a process?

- The idea ... leverage as much as possible historical data:
  - ▶ Method 1: Augment "most reliable" historical datapoints with Space Filling Design
  - ▶ Method 2: Reduce experiment cost of Custom Design by leveraging historical data





# Conclusions and open questions

- JMP is a very powerful tool to perform DOE
- DOE for world scale manufacturing processes proves very challenging:
  - ▶ Low signal to noise ratio
  - ▶ Very limited experimental time and resources
  - ▶ Change management
- Dedicated workflows could help improve DOE application in process industry:
  - ▶ What is the most informative next experiment?
  - ▶ How to make optimal use of historical data in combination with DOE?
  - ▶ How to calculate the trade-off between the value of additional experiments and the incurred costs?

# Let's all set sail and explore new possibilities



*“It is easy to discover what another has discovered before.”*

**Christopher Columbus**





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