

# Computational Modeling with VPython

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YOU'RE TRYING TO PREDICT THE BEHAVIOR  
OF <COMPLICATED SYSTEM>? JUST MODEL  
IT AS A <SIMPLE OBJECT>, AND THEN ADD  
SOME SECONDARY TERMS TO ACCOUNT FOR  
<COMPLICATIONS I JUST THOUGHT OF>.

EASY, RIGHT?


SO, WHY DOES <YOUR FIELD> NEED  
A WHOLE JOURNAL, ANYWAY?



LIBERAL-ARTS MAJORS MAY BE ANNOYING SOMETIMES,  
BUT THERE'S *NOTHING* MORE OBNOXIOUS THAN  
A PHYSICIST FIRST ENCOUNTERING A NEW SUBJECT.




# What is Computational Modeling?



# WolframAlpha



WolframAlpha<sup>®</sup> computational knowledge engine

Enter what you want to calculate or know about:



 Examples  Random



# Molecular Models





# Examples from Fermilab

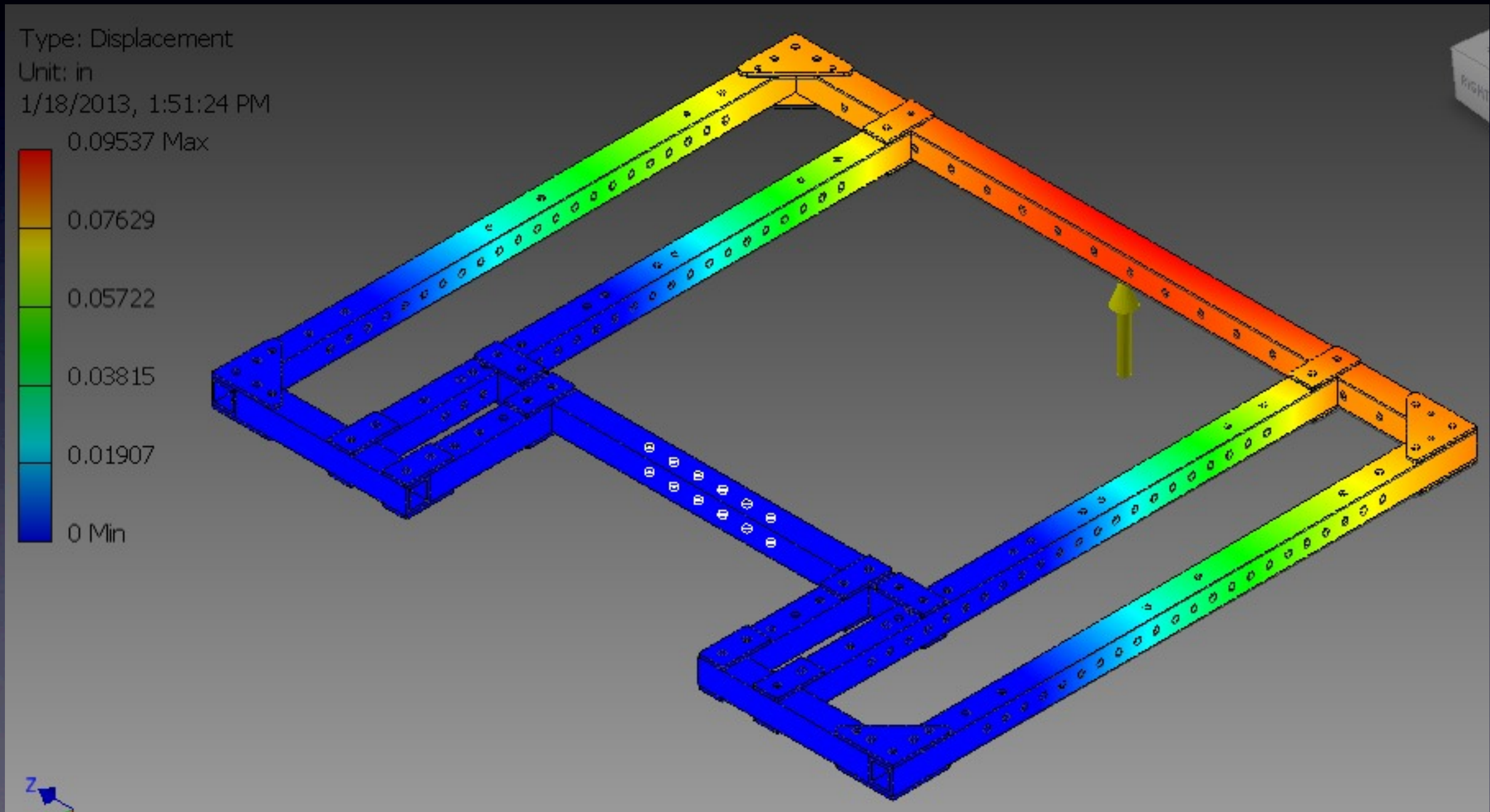
- Monte Carlo simulations to predict frequency of decay products from other particles when looking for Higgs
- dark matter distribution throughout the Milky Way simulations
- design and tuning of 40-m long interferometer



# High-Altitude Balloon Path

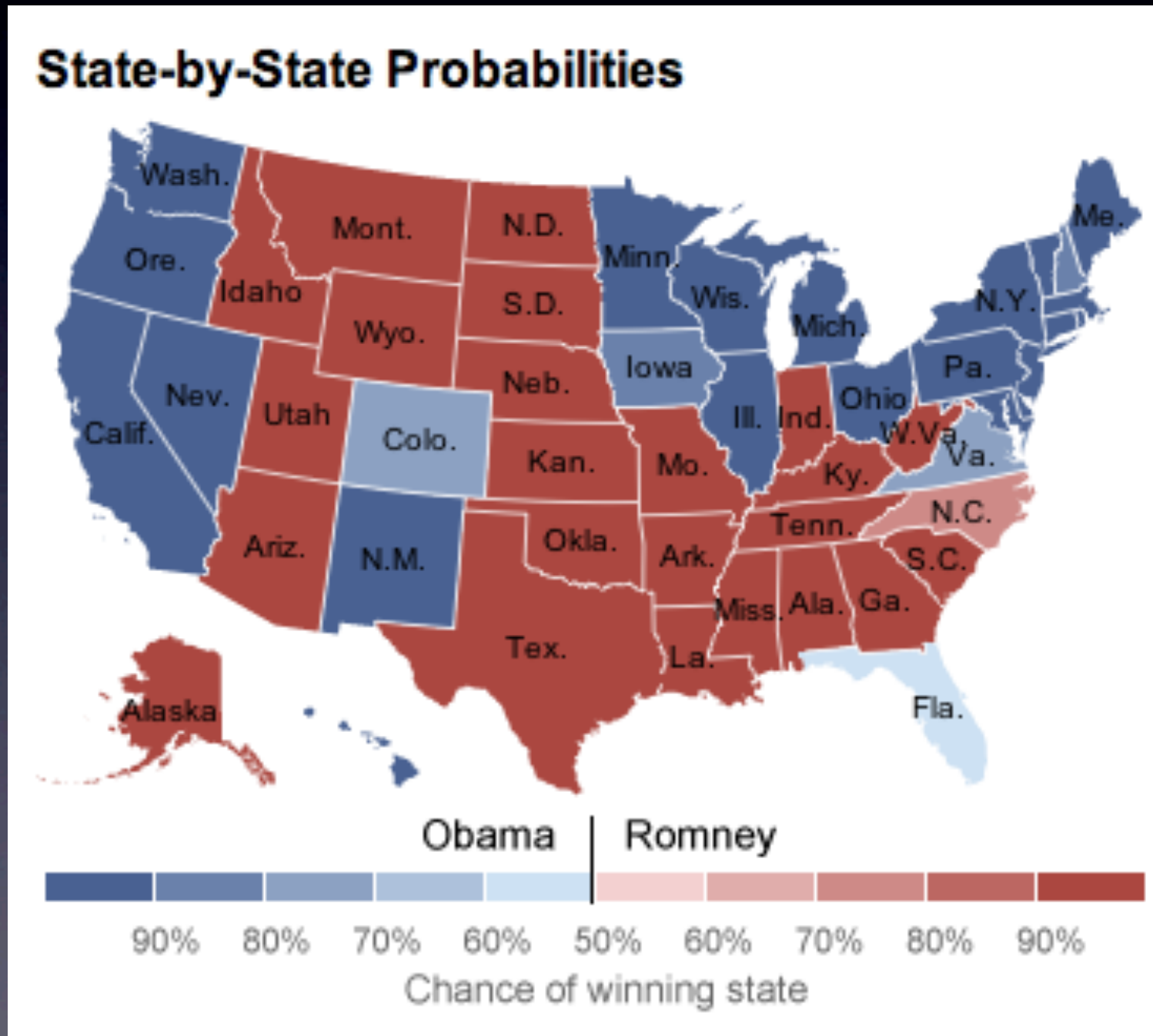


# Finite Element Analysis



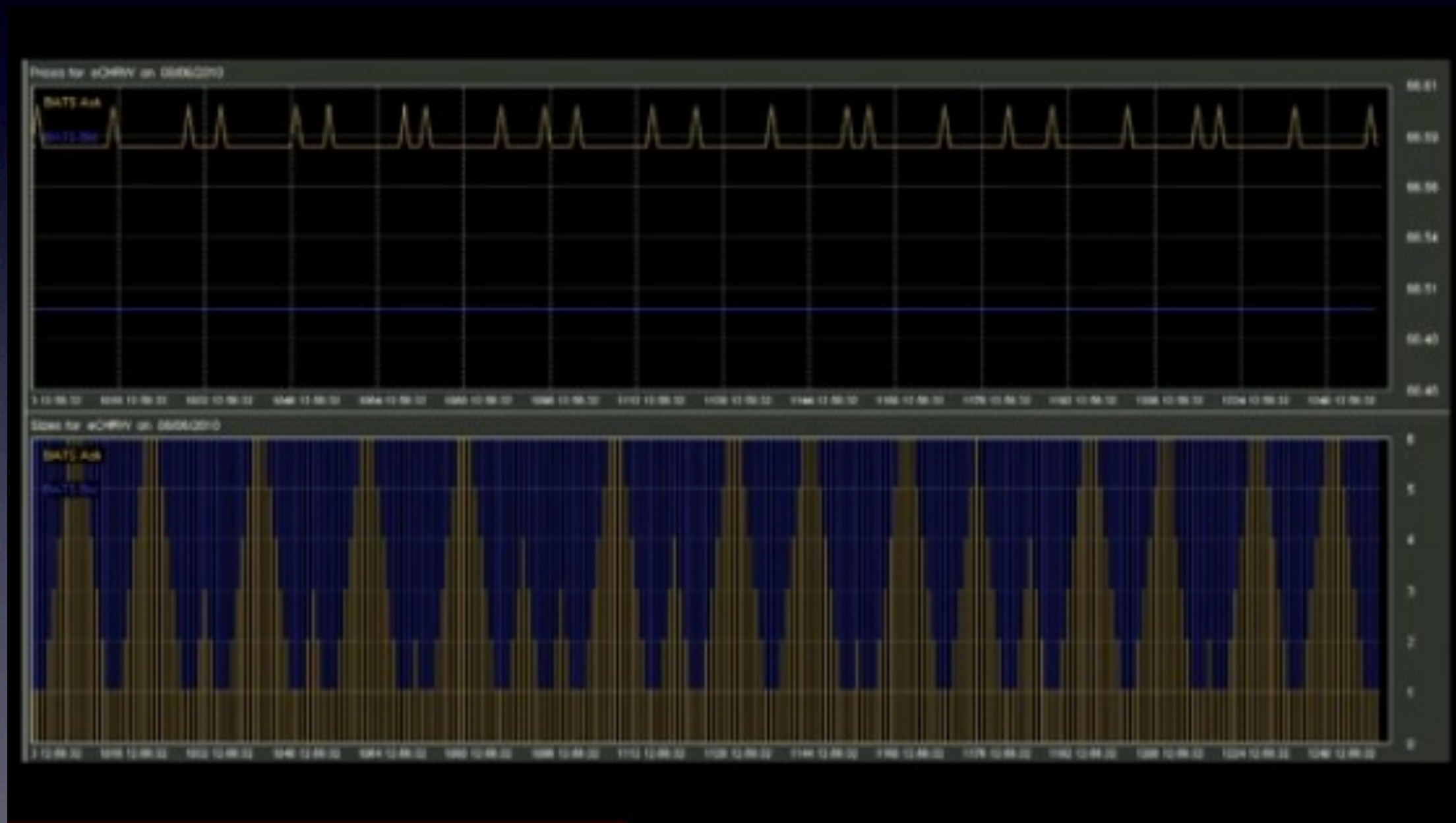


# Politics

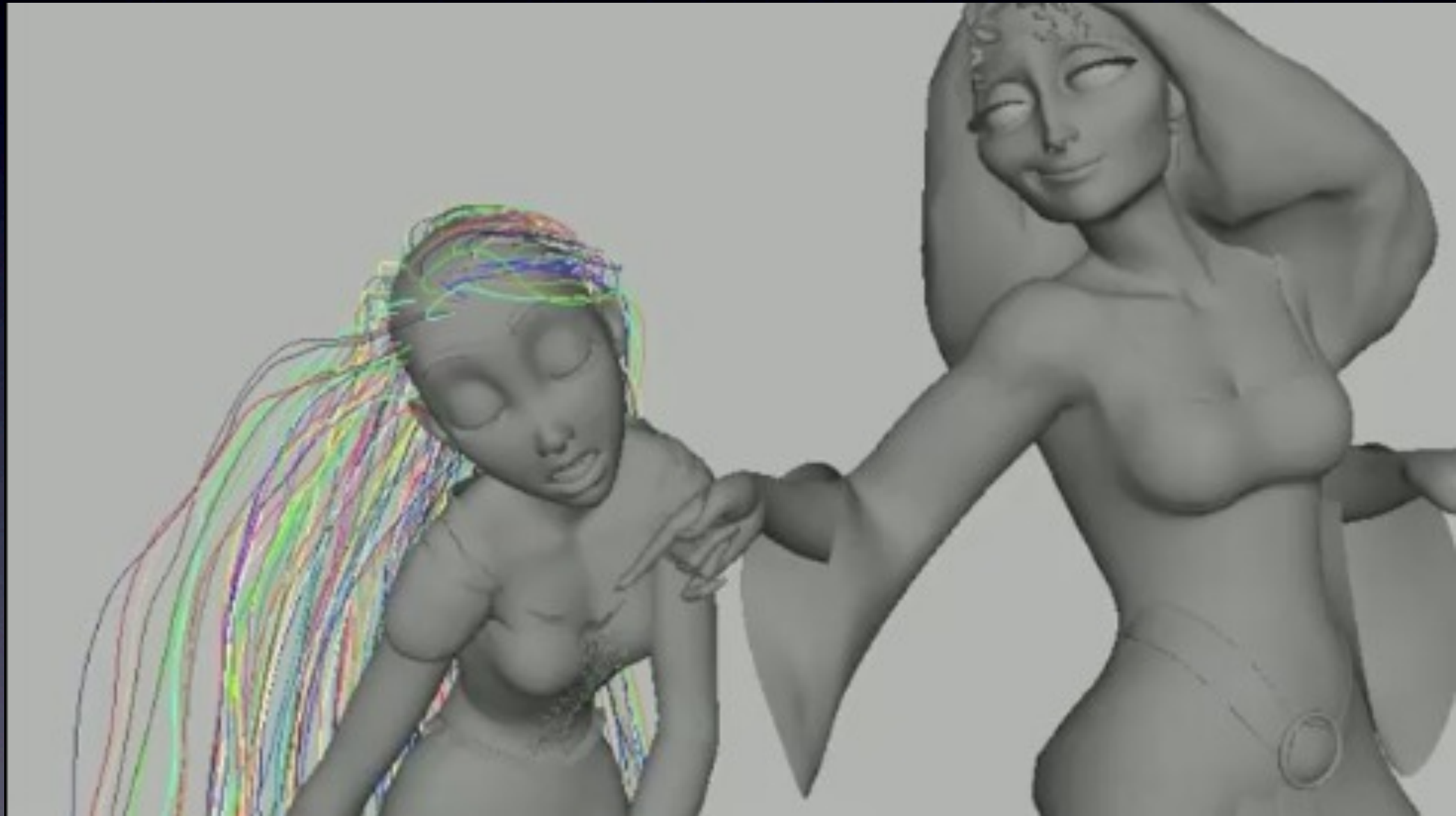




# Black Box Trading (Algo Trading)



# Rapunzel's Hair





# More Than Programming

- computational thinking is
  - knowing when and how to use a computer to solve a problem
  - mapping from the problem space to the solutions space by creating an algorithm
- programming is just one part

# More Than Running Simulations

- not sufficient to develop computational thinking
- students need to modify, extend, and create their own computational models



# Why Teach Computational Modeling?

# Increase Understanding

- multiple representations of concepts
  - verbal, mathematical, graphical, diagrammatical, and computational
- reinforce key idea of models predicting the future and explaining the past
- encourages exploration (what if?)



# Authenticity

- enable students to explore more complex problems whose solutions are beyond the scope of their current course

# Next Generation Science Standards

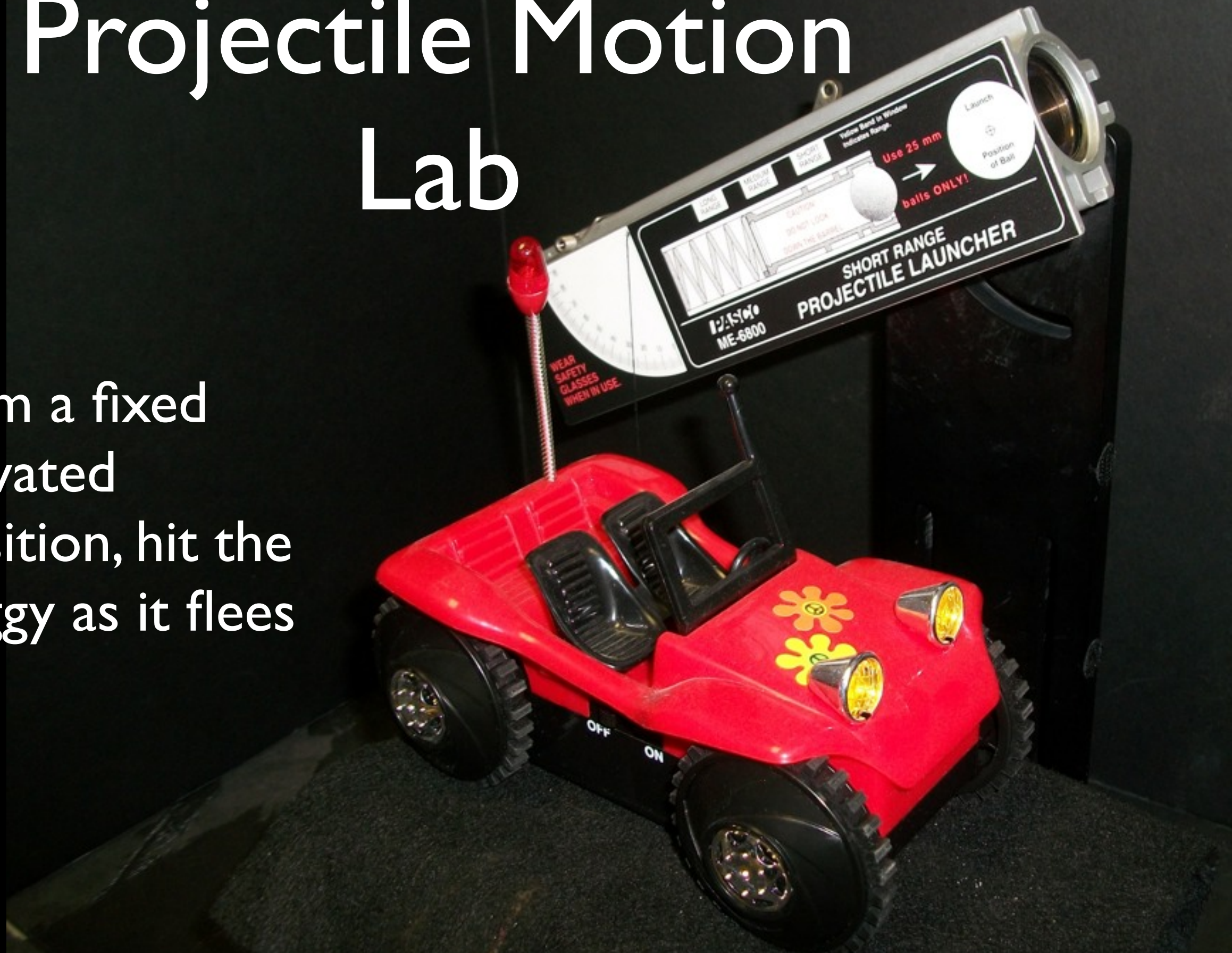
- Science and Engineering Practices
  - Analyzing and Interpreting Data
  - Using Mathematics and Computational Thinking
  - Developing and Using Models
- refer to computational thinking and students using and creating computational models and simulations



# I -dMotionSimulation.py

# Projectile Motion Lab

- from a fixed elevated position, hit the buggy as it flees





# Projectile Motion Lab

# Projectile Motion Result





# Science Olympiad

## Gravity Vehicle

- gravity-powered vehicle on a ramp rolls as fast as possible a specified (but unknown until that day) distance
- scoring based on accuracy, time, and minimizing height of ramp
- computational model used to verify calculation and explore impact of various distances

# Science Olympiad Gravity Vehicle



# Gravity Vehicle Results

breaking distance (m): 9.4

initial velocity (m/s): 2.4248711306

final time (s): 4.372

final cart position (m):  $\langle 10, 0, 0 \rangle$

height score: 44.4444444444

time score: 109.3

total score (low score wins): 153.7444444444

# Visualize

- energy transfers: `massOnSpring.py`
- position, velocity, acceleration relationships: `shm.py`



# Explore

- orbits: `satellite.py`, `binary.py`
- fluids: `buoyancy.py`

# Resources

- Georgia Tech PER Group
  - <https://per.gatech.edu/wiki/doku.php?id=projects:hscomp:physutil>
- my GitHub
  - <https://github.com/gcschmit/vpython-physics>
- John Burk's blog
  - <https://quantumprogress.wordpress.com/computational-modeling/>



# Textbooks

- Matter and Interactions by Ruth Chabay and Bruce Sherwood
  - <http://matterandinteractions.org>
- *Computational Physics* by Mark Newman
  - <http://www-personal.umich.edu/~mejn/cp/>

# Alternative Computational Modeling Tools

- Open-Source Physics Easy Java Simulations (OSP EJS)
- Glowscript
- GeoGebra



# Papers

- Integrating Numerical Computation into the Modeling Instruction Curriculum
  - Caballero, Burk, et al.
  - <http://arxiv.org/abs/1207.0844>