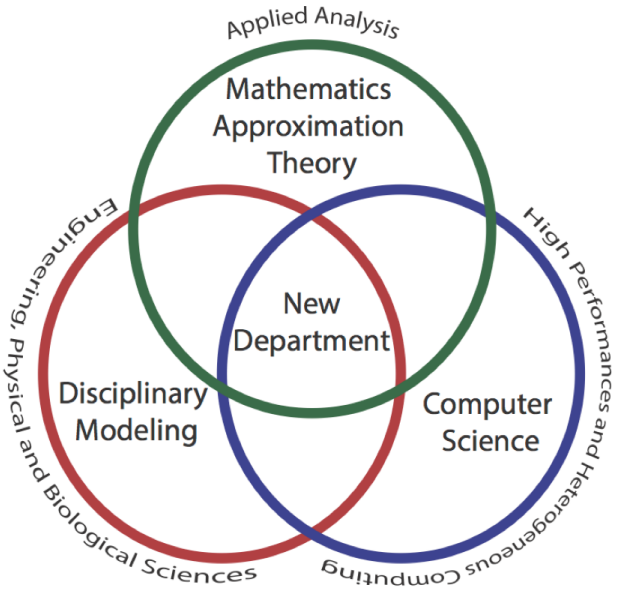
Computational Mathematics, Science and Engineering (CMSE): Establishing an Academic Department Dedicated to Scientific Computation as a Discipline

Department of Computational Science, Mathematics and Engineering



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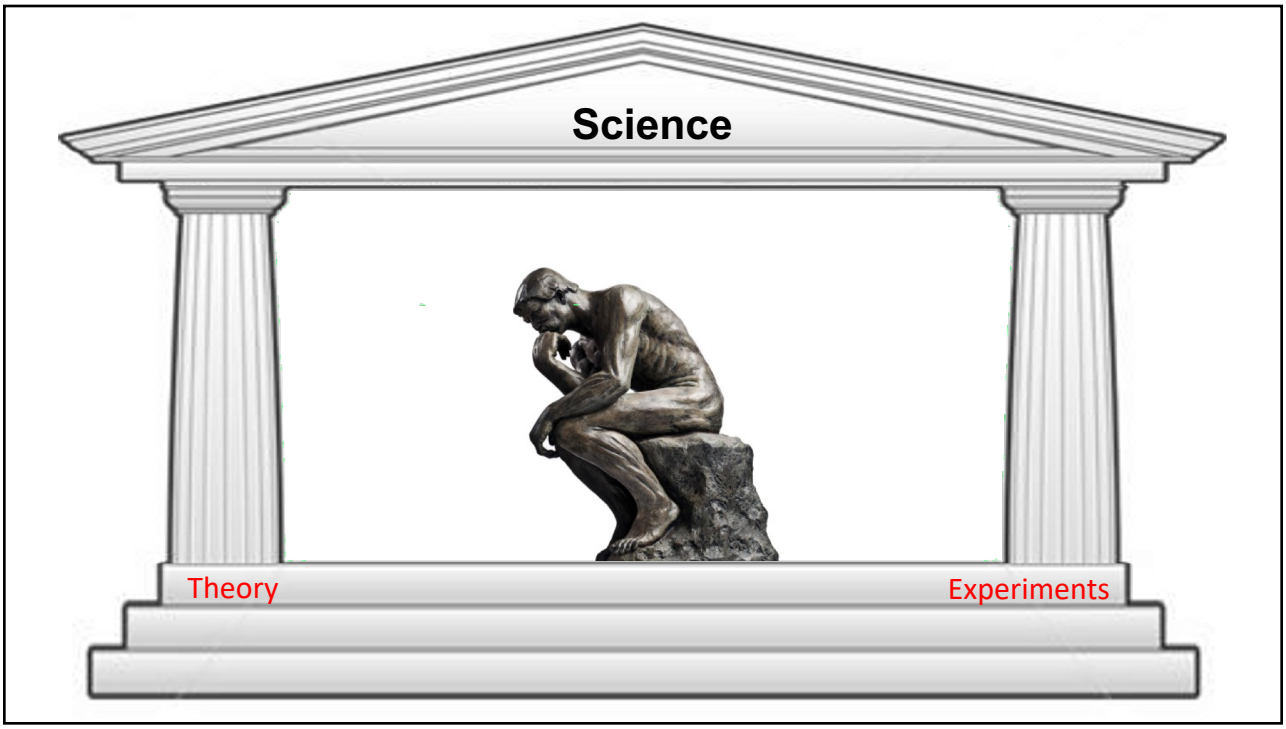

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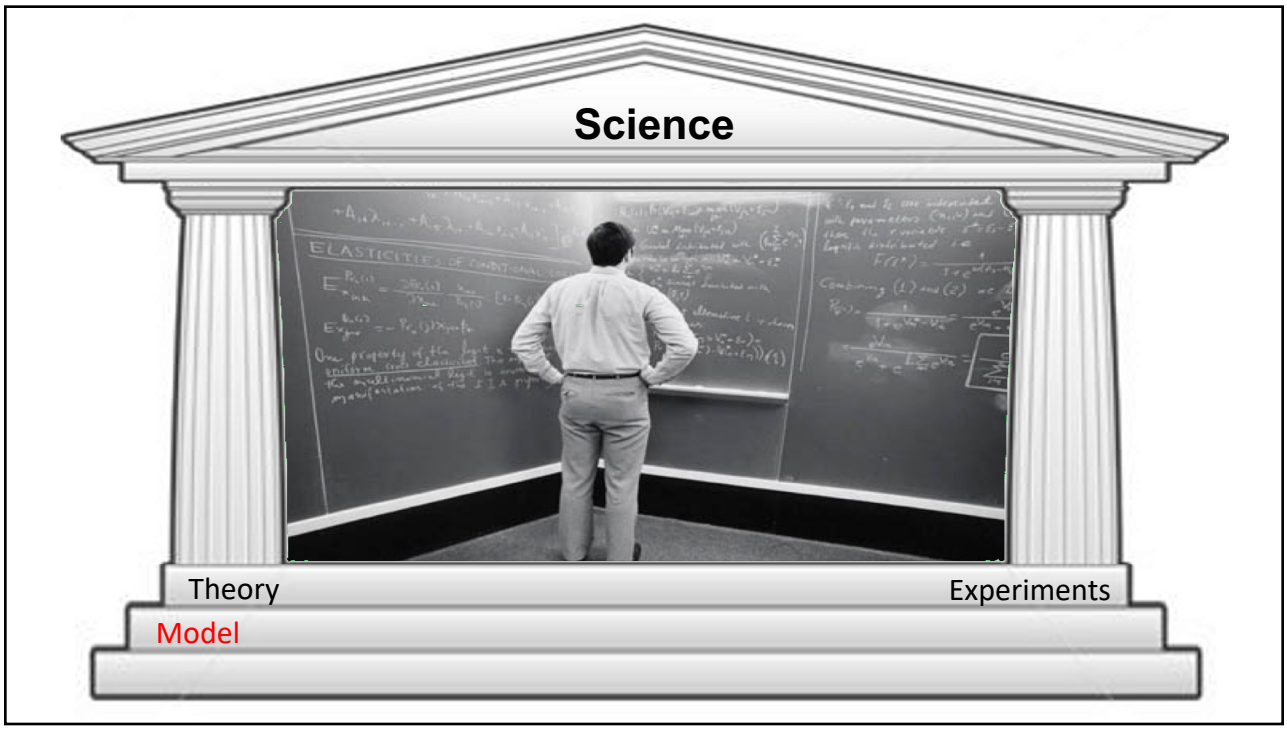
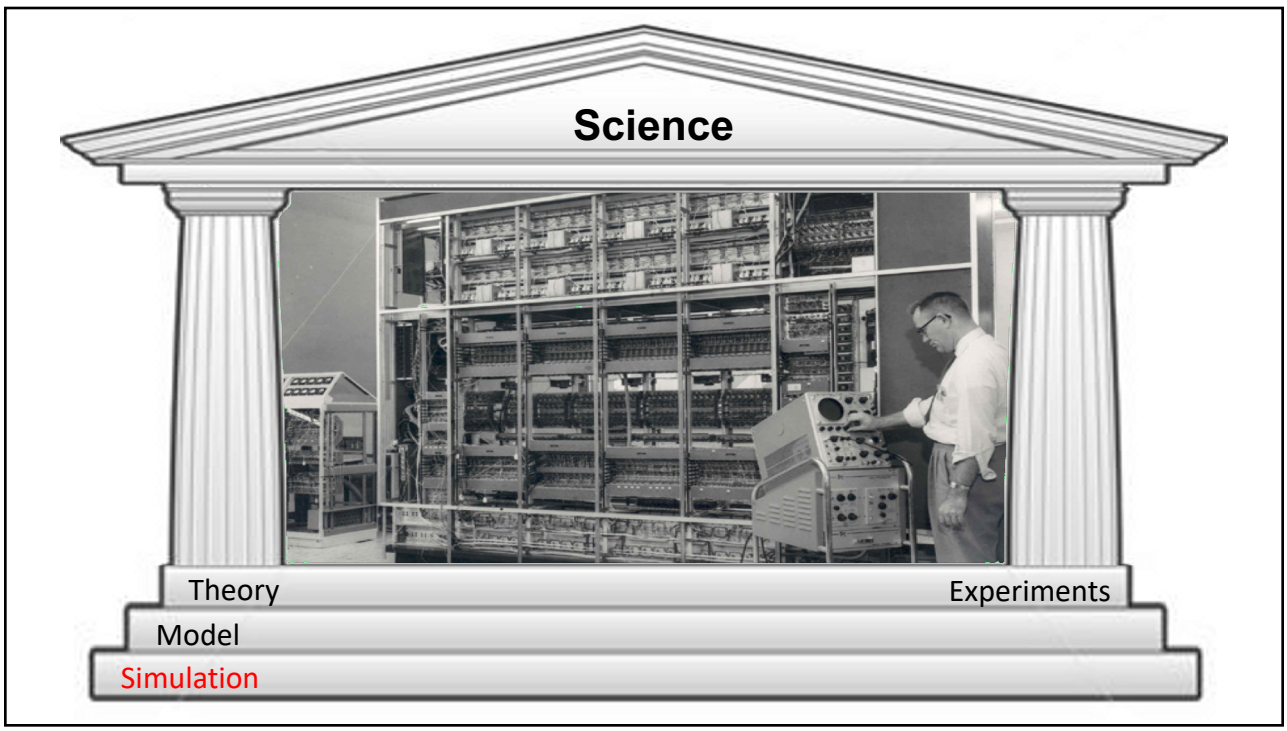
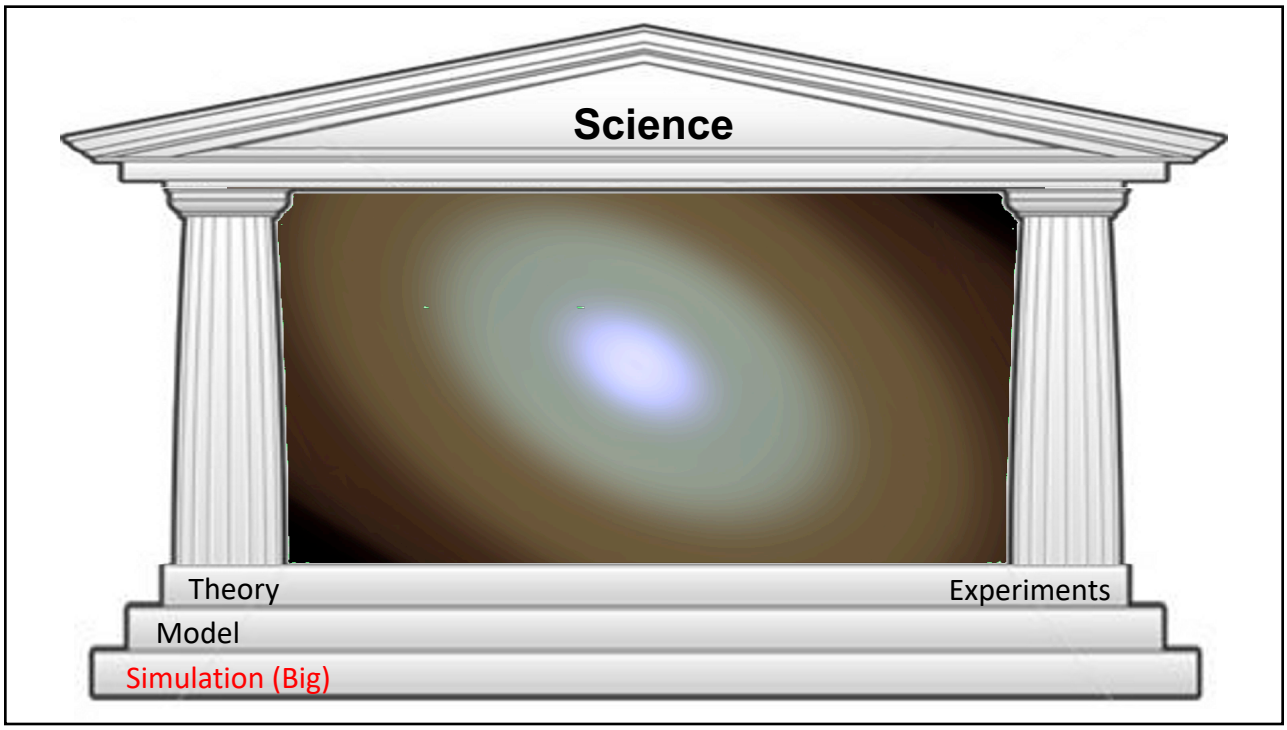

Science
Theory
Experiments
Model

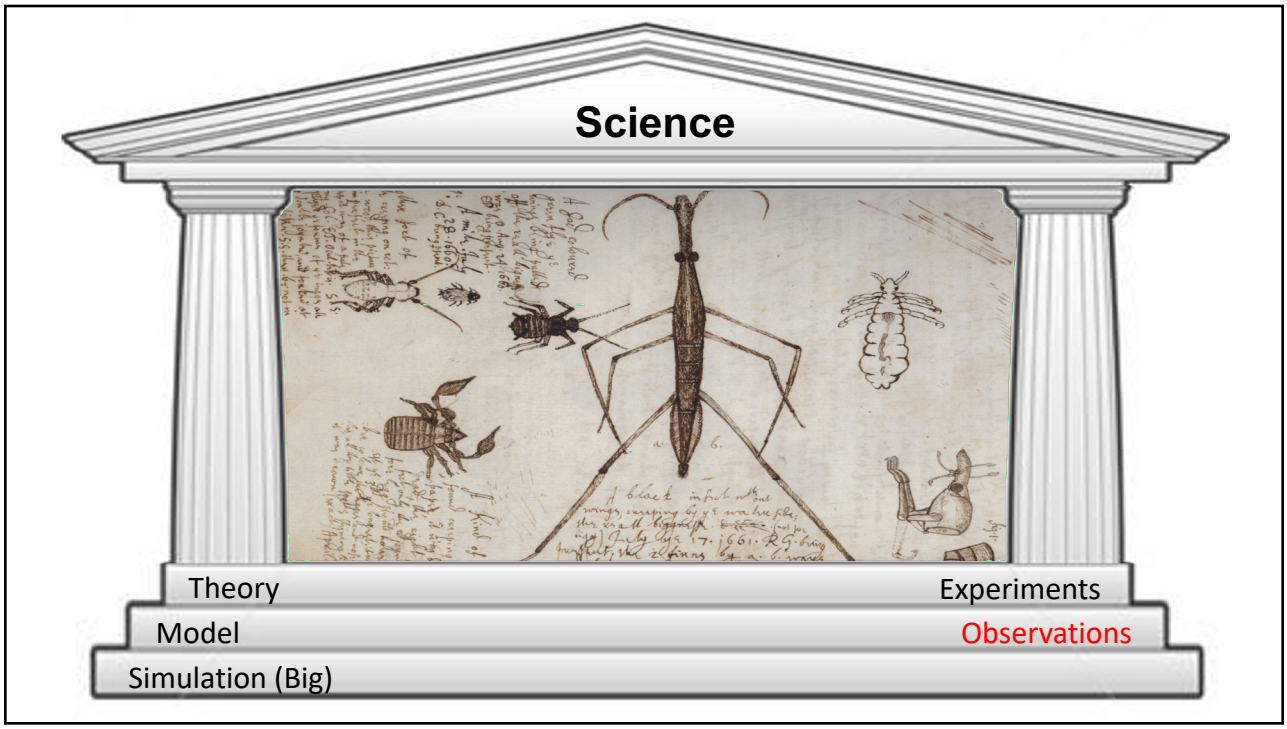
3


Science
Theory
Experiments
Model
Simulation

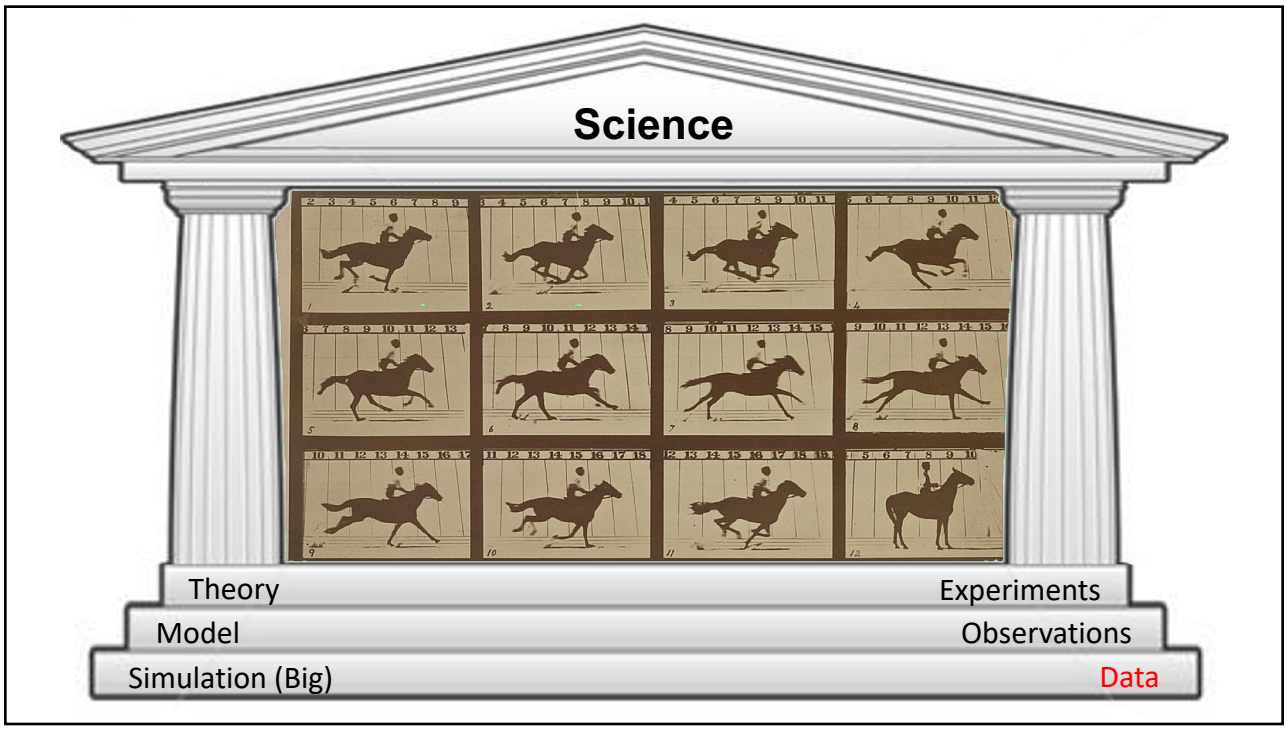
4


Science
Theory
Experiments
Model
Simulation (Big)

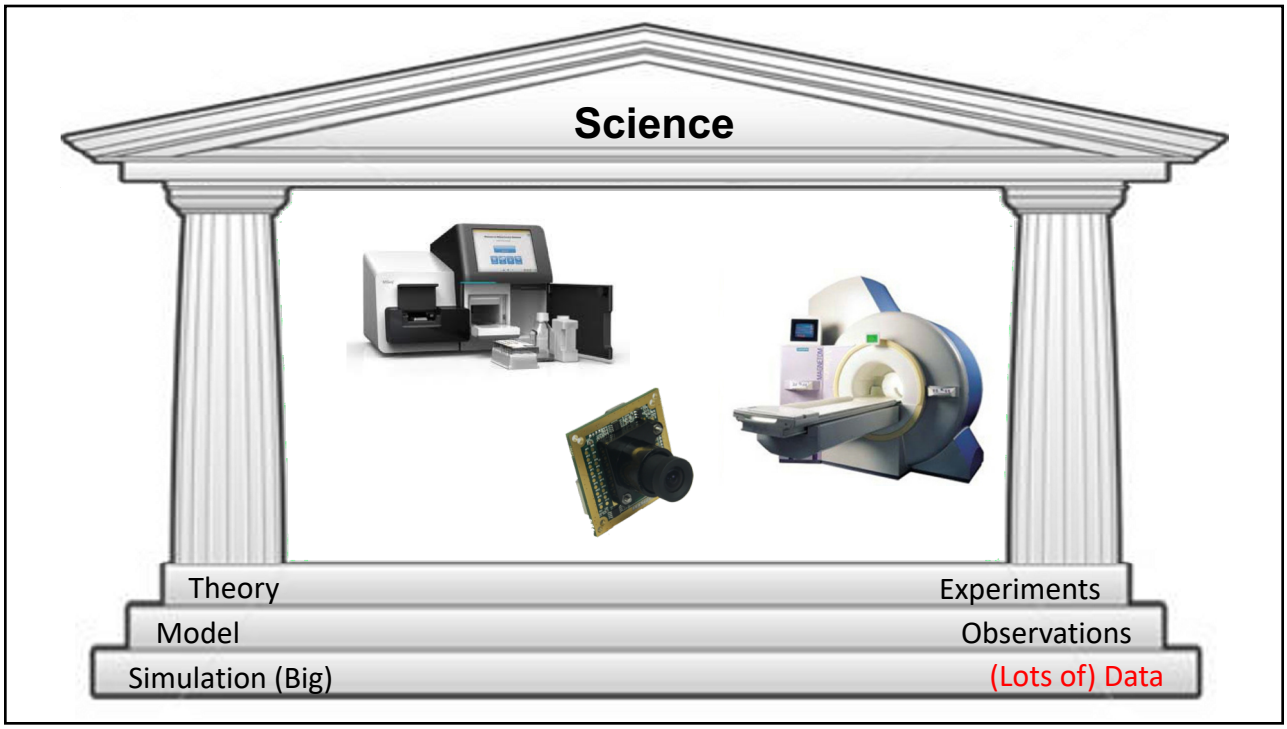
5


Science
Theory
Experiments
Model
Observations
Simulation (Big)

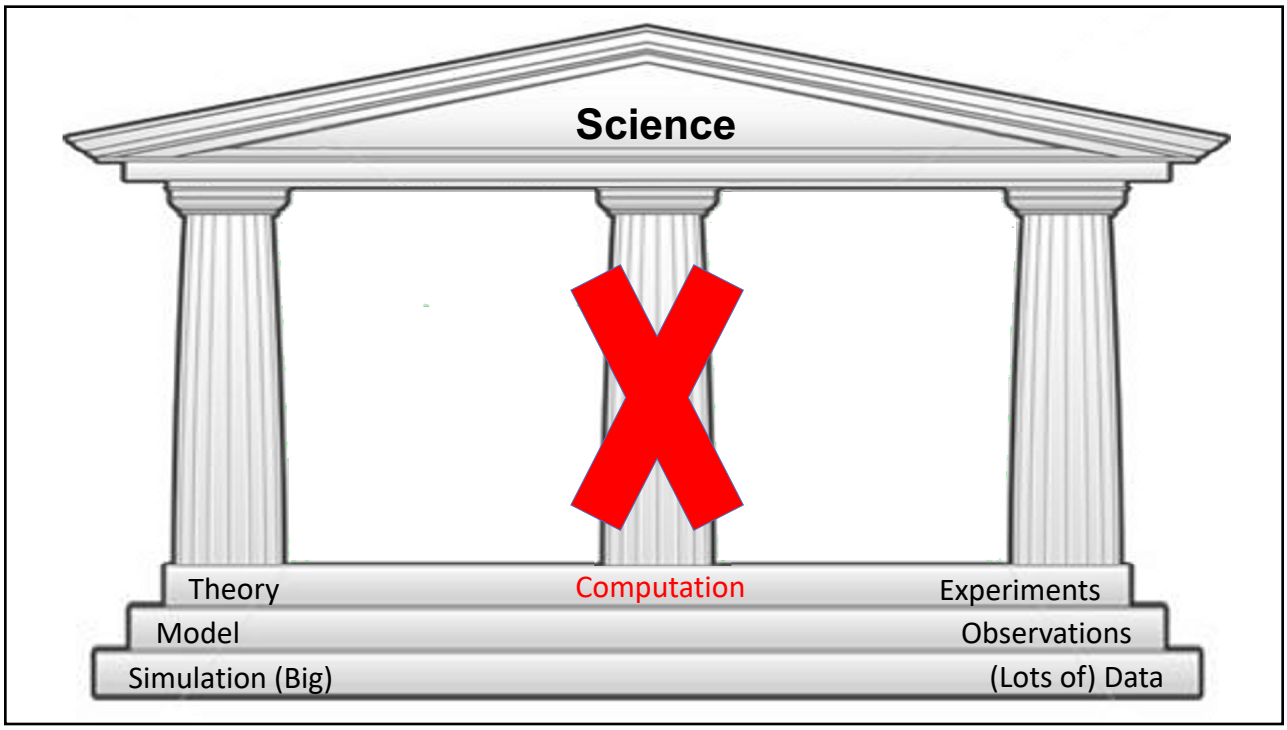
6


Science
Theory
Experiments
Model
Observations
Simulation (Big)
Data

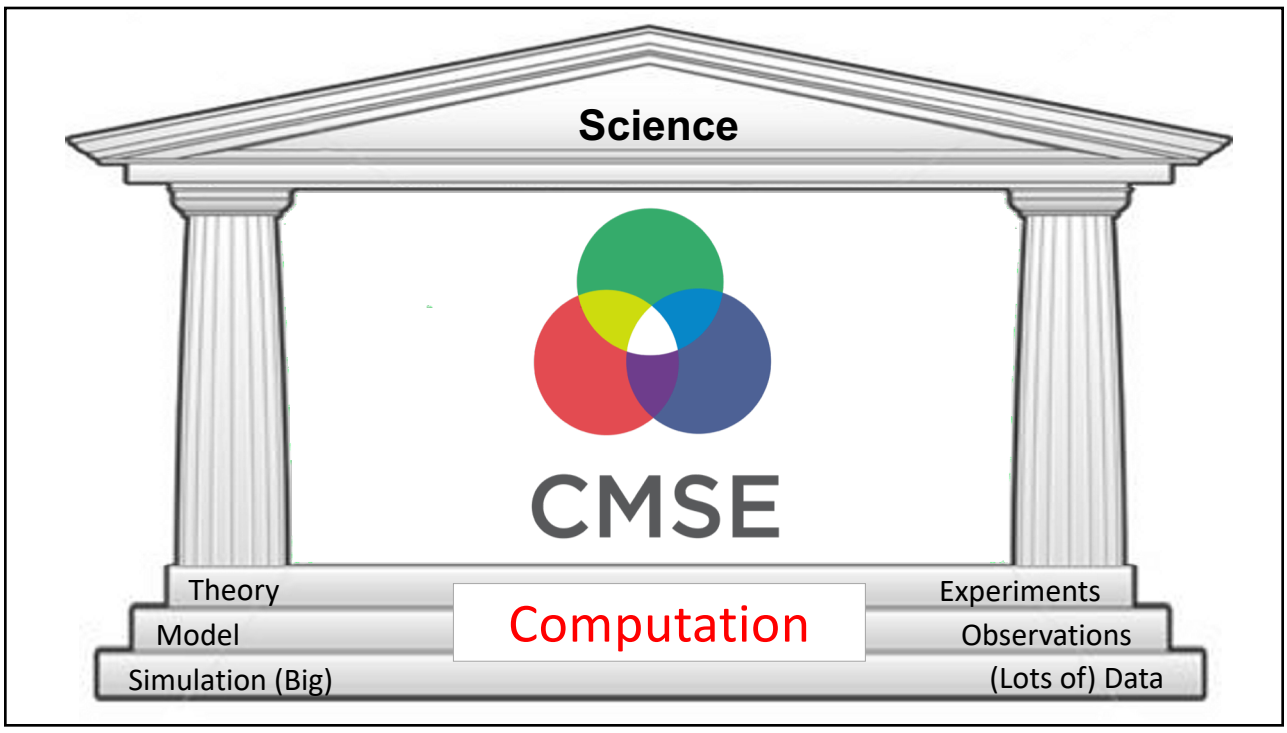
7


Science
Theory
Experiments
Model
Observations
Simulation (Big)
(Lots of) Data

8


Science
Theory
Model
Simulation (Big)
Computation
Experiments
Observations
(Lots of) Data

9


Science
CMSE
Theory
Model
Simulation (Big)
Computation
Experiments
Observations
(Lots of) Data

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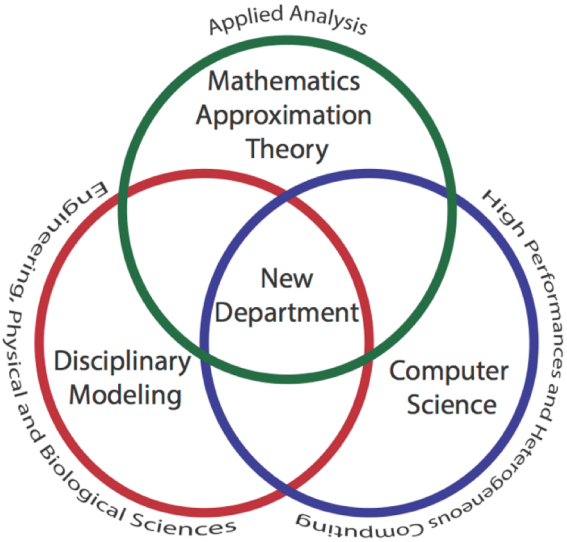
The idea: Build a new educational unit

Computational science: using computers to analyze and solve scientific and engineering problems.

Knock down silos



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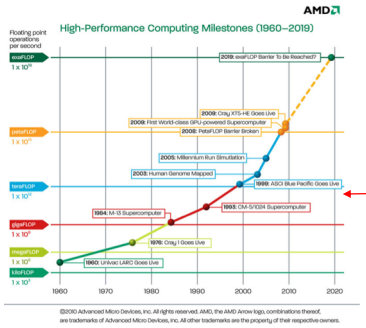
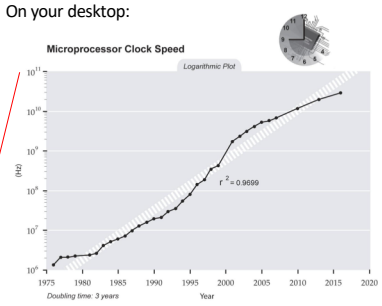
Why Now?

The world is changing, and Science/Engineering needs to change with it.

High performance **computing** pervades all of science and engineering today.



On your desktop:



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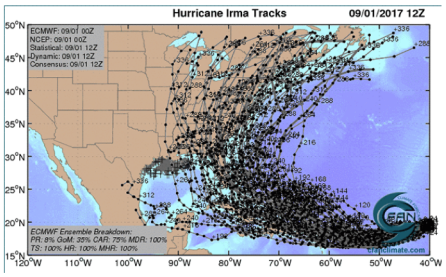
Why Now?

The world is changing, and Science/Engineering needs to change with it.

Advanced **algorithms** are changing the way we predict and control our world.



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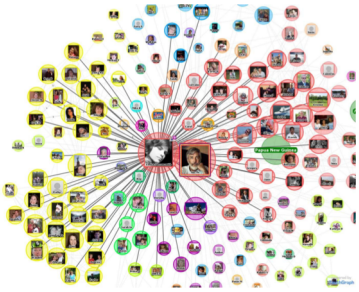
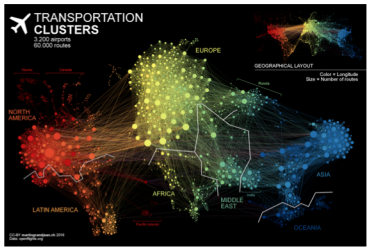
Why Now?

The world is changing, and Science/Engineering needs to change with it.

Data is be generated at unprecedented rates from unprecedented sources with unprecedented uses.





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What are the options and issues?

Options:

- A new Degree
- A University Center or Institute
- A New Department

Major Issues:

- Where would it live?
- How would it be managed?
- Where will we get the resources?
- How long will it last?

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Good: A New Degree

Pros:

- Fast / Easy to implement given current university bureaucracy.
- Existing administrative resources to build from.

Cons:

- Which department owns the new major and takes up the responsibility?
- What do these departments give up to make the new degree?

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Better: A University Center or Institute

Pros:

- Strong support from university if built from grant support.
- Does not take resources away from existing units.
- Can be centrally located and help break down silos between units.

Cons:

- Generally requires a grant or external funding to move forward.
- Often does not live past the lifetime of the grants.
- Does not easily allow for a degree program.

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Best: A New Department

Pros:

- Likely to stick around for a long time and represents a strong buy-in from the university.
- Ability to build a solid culture/program from scratch.
- Allows for multiple degree programs.

Cons:

- Very costly and often requires scavenging funds and people from existing departments.
- Requires buy-in/approval from entire university.
- If done incorrectly could become just another silo.

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Where do the resources come from?

- Faculty?
- Staff?
- Space?

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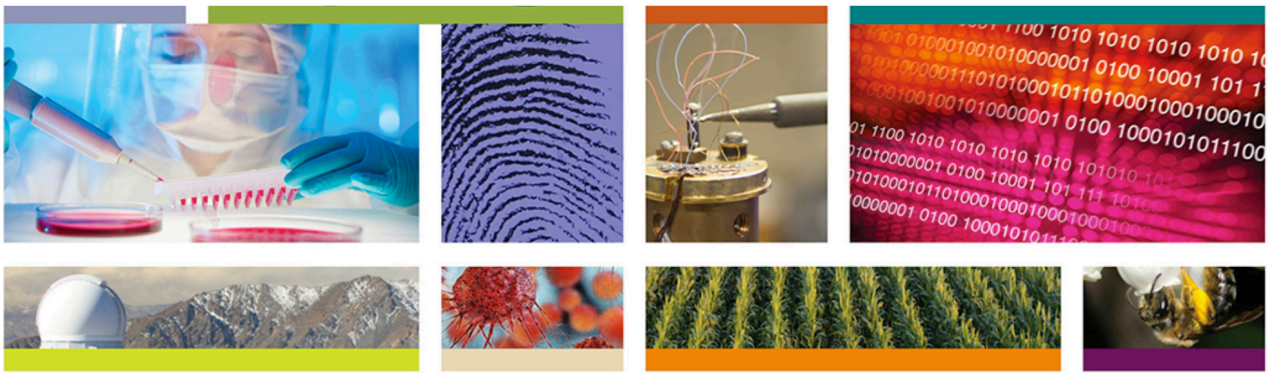
Global Impact Initiative
MICHIGAN STATE UNIVERSITY

Research@MSU



Through the MSU Global Impact Initiative, MSU will recruit more than 100 new faculty investigators to our research team to help accelerate finding solutions to the recognized "Grand Challenges."

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CMSE

Department of Computational Mathematics Science and Engineering

Est. 2015

- Jointly operated by Colleges of Natural Science and Engineering
- Composed of 25-30 FTEs, including some current MSU faculty and a larger number of **new hires.**
- Most faculty will have joint appointments across campus.
- Faculty focus on data science and large-scale/high-performance computation
- Faculty are incentivized to engage in cross-discipline and cross-college research collaborations

ENGINEERING

http://cmse.msu.edu

NatSci

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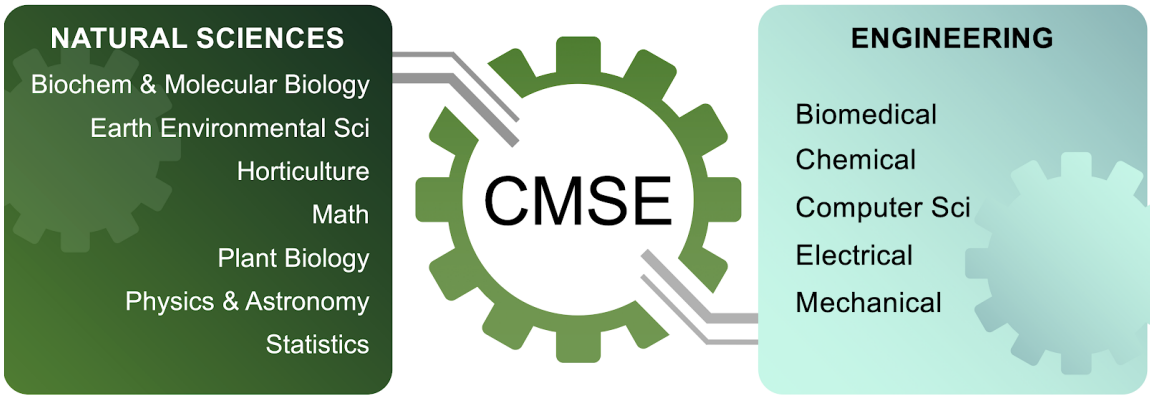

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Educating the modern workforce

Modern STEM workers need to be able to build and use computational models, analyze massive amounts of data, and communicate these results to make decisions.

CMSE is meeting these needs for internal and external partners!

- Introductory courses (undergrad and grad)
- Undergrad minor and graduate certificates
- Bioinformatics training
- CMSE PhD and dual PhD programs
- Fall 2019 - BS in Data Science
- Comming 2021 – MS in Data Science

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STEM Gateway Courses

CHEMISTRY

PHYSICS

BIOLOGY

MATH

COMPUTATION

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CMSE 201/202 Computational Modeling

- CMSE 201- **Introduction to Computational Modeling**
- CMSE 202 - **Computational Modeling - Tools and Techniques**
  - Working with data: analysis and visualization
  - Creating models
  - Comparing data to models

- Very popular! 4 sections (x 36 to 70 students/section)
- CMSE 201 now required for all data science, physics/astrophysics and biochemistry majors, selective in Economics BA/BS and Quantitative Social Science minor (growing trend in this direction)

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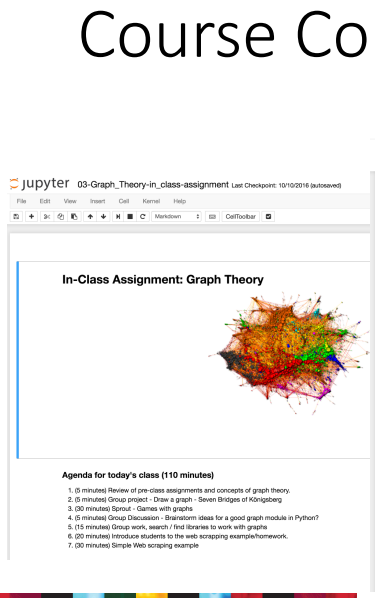
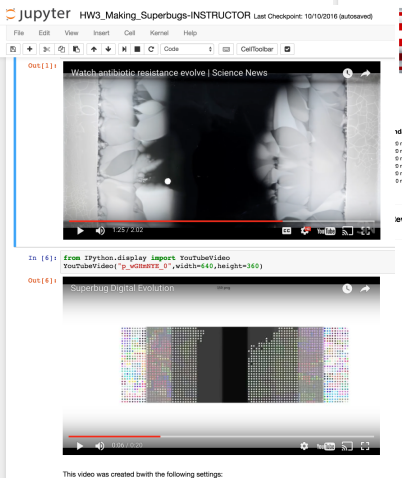
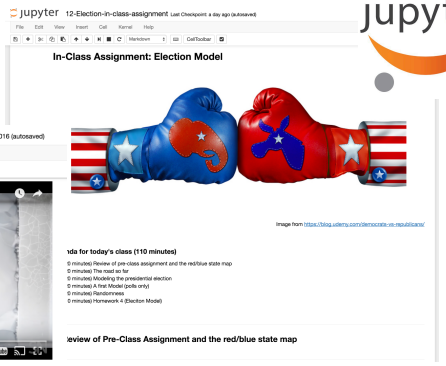
Course Content







- **Training in Computational Modeling**
- **Focus on Models with Social Impact**
- **Core Gateway Classes**
- **Flipped Classrooms**
- **Multidisciplinary**

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ENGINEERING

NatSci

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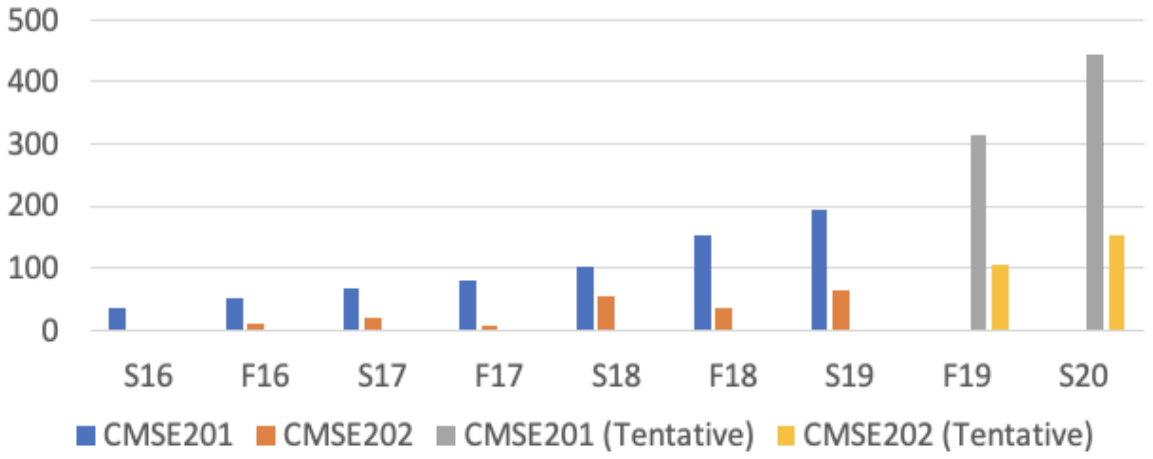
Growth of 201/202



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Graduate Service Courses

CMSE 801 - INTRO TO COMPUTATIONAL MODELING

CMSE 802 – METHODS IN COMPUTATIONAL MODELING

BIOINFORMATICS TRAINING: CROSS DISCIPLINE TOOLS

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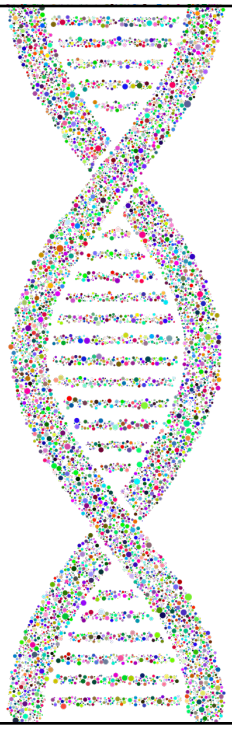
Bioinformatics

- Centralized bioinformatics training program supporting graduate students and post-docs in 6 colleges and ~2 dozen departments.
- Program intended to be highly modular and extensible: 1-credit courses with short prerequisite chains

Designed specifically to support life science grad student needs



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PhD in CMSE

Core graduate qualifier courses

- Math foundations of Data Science
- Numerical Differential Equations
- Parallel Computing
- Numerical Linear Algebra

Special topics courses

- Optimization
- Topological Analysis of Large Datasets
- Computational Methods for Uncertainty Quantification
- Scientific Image Understanding
- Particle-Based Simulation Methods
- Next generation computing Architectures
- Etc.

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MSU Dual Major program

- Single Dissertation
- Research reflects contributions to both majors
- Students must satisfy some of the qualifier requirements in both majors
- Program is extremely popular

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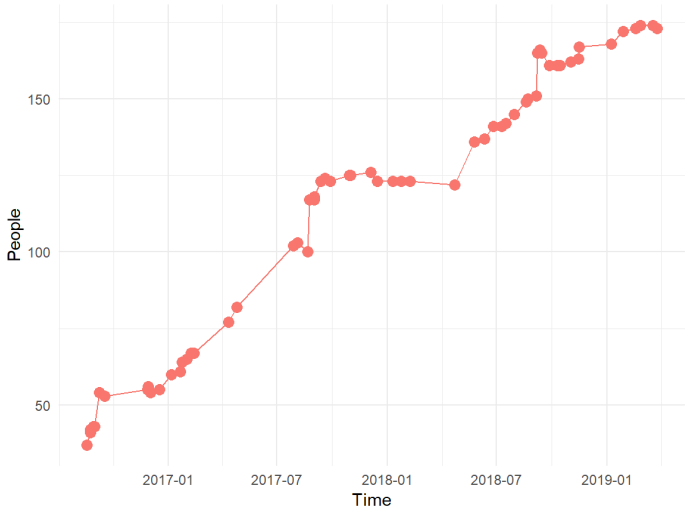
Full-time Departmental Growth



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Future Work

- Continue to develop our undergraduate programs.
- Internships for graduate and undergraduate students.
- Hiring more faculty including an external chair.
- Connecting with other universities and institutions to promote the idea of computation as an academic discipline.

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