



# CODE @ ms-cc

STUDENT HACKATHON

**TACC**  
TEXAS ADVANCED COMPUTING CENTER



<https://hackhpc.github.io/codeatms-cc23>



# WELCOME TO TACC

# Introductions - Icebreaker



Charlie Dey (*TACC*)



Je'aime Powell (*TACC*)



# TACC AT A GLANCE

- ▶ Research center located at UT Austin
- ▶ ~175 Staff (~70 PhD scientists, ~20 students)
- ▶ Funded by UT System, NSF (85% external grants)
  
- ▶ **Users:** >10,000 on 2,300 active projects across all fields
- ▶ **Partnerships:** UT Research Cyberinfrastructure (UTRC), Extreme Science and Engineering Discovery Environment (XSEDE), Industry, International



**Mission:** “To enable discoveries that advance science and society through the application of advanced computing technologies.”

# TACC AT A GLANCE

## ► Capacity and Infrastructure:

- A billion compute hours per year
- >5 billion files, >50 petabytes of data
- Hundreds of public datasets
- 18 MW data center

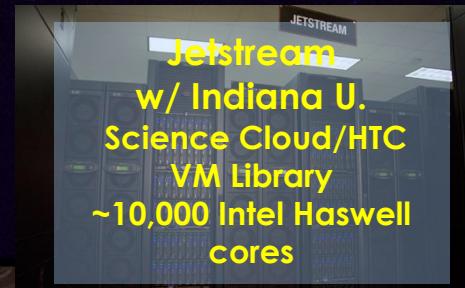
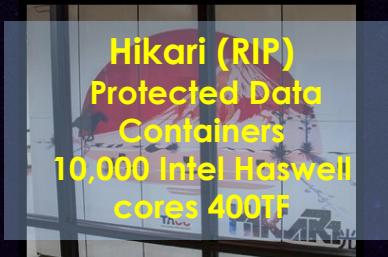
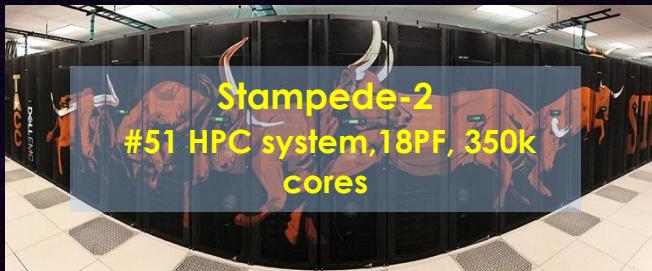


## ► Systems and Services:

- High performance computing (HPC), high throughput computing (HTC), large scale data storage, cloud computing, visualization
- Portals and gateways, web service APIs, rich software stacks
- Consulting, curation and analysis, code optimization, training and outreach



# AN ECOSYSTEM FOR EXTREME SCALE SUPERCOMPUTING



# EXPERIMENTAL SYSTEMS



# **"COMPUTING FOR THE ENDLESS FRONTIER"**

Dan Stanzione

Executive Director, Texas Advanced Computing Center

Associate Vice President for Research, The University of Texas at Austin

# FRONTERA



TACC



TEXAS

# RAPID GROWTH FROM THEN TO NOW...

- ▶ 2003 – First Terascale Linux cluster for open science (#26)
- ▶ 2004 – NSF funding to join the Teragrid
- ▶ 2006 – UT System Partnership to provide Lonestar-3 (#12)
- ▶ **2007 - \$59M NSF award – largest in UT history – to deploy Ranger, the world's largest open system (#4)**
- ▶ 2008 – funding for new Vis software and launch of revamped visualization lab.
- ▶ 2009 - \$50M iPlant Collaborative award (largest NSF bioinformatics award) moves a major component to TACC, life sciences group launched.
  - ▶ In 2009, we reached, 65 employees.



# NOW, A WORLD LEADER IN CYBERINFRASTRUCTURE

- ▶ 2010, TACC becomes a core partner (1 of 4) in XSEDE, the TeraGrid Replacement
- ▶ 2012, Stampede replaces Ranger with new \$51.5M NSF Award
- ▶ 2013, iPlant is renewed, expanded to \$100M
- ▶ 2015, Wrangler, first data intensive supercomputer is deployed.
- ▶ 2015, Chameleon cloud is launched
- ▶ 2015, DesignSafe, the cyberinfrastructure for natural hazard engineering, is launched.
- ▶ 2016 Stampede-2 awarded the largest academic system in the United States, 2017-2021.



# FRONTERA SYSTEM --- PROJECT

- ▶ Deploy a system in 2019 for the largest problems scientists and engineers currently face.
- ▶ Support and operate this system for 5 years.
- ▶ Plan a potential phase 2 system, with 10x the capabilities, for the future challenges scientists will face.

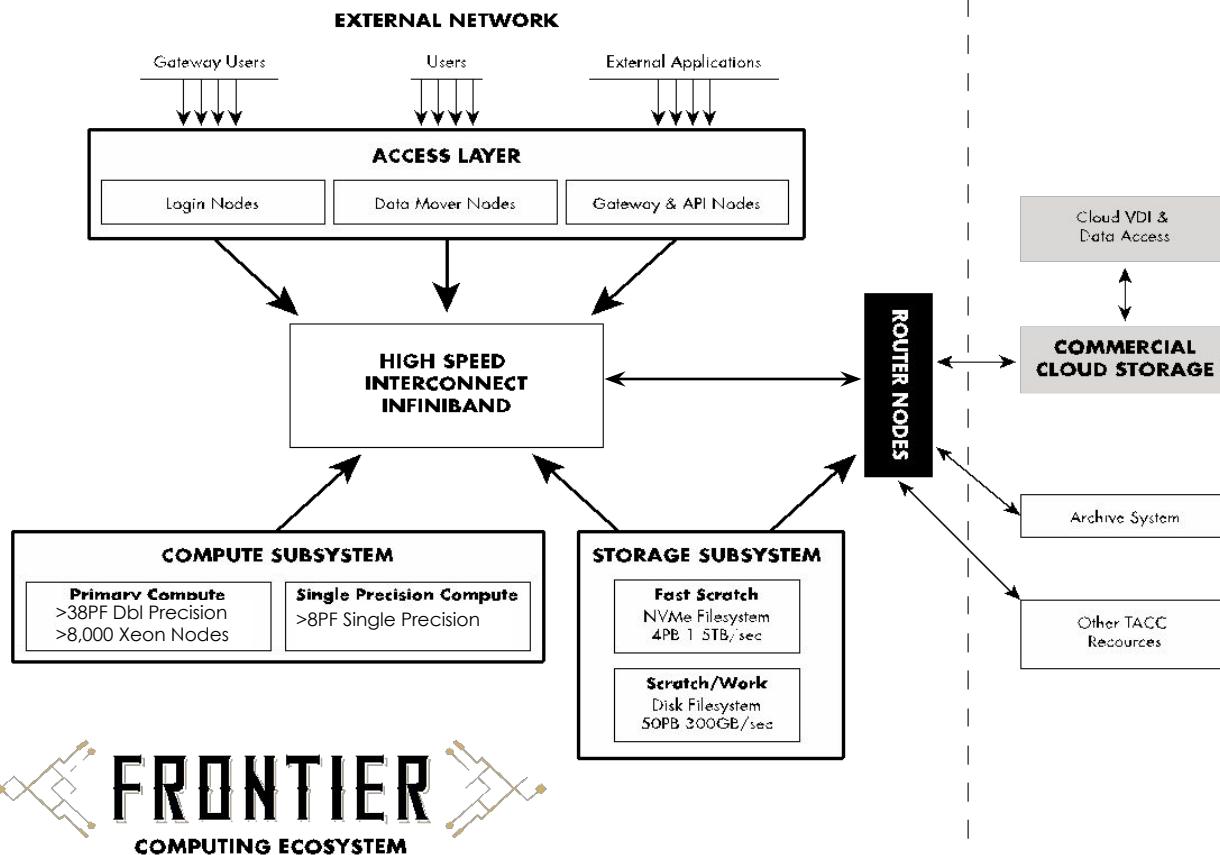


# FRONTERA SYSTEM ---- HARDWARE

- ▶ 8th Fastest Supercomputer in the world
  - ▶ #1 for Open Science
- ▶ Primary compute system: DellEMC and Intel
  - ▶ 35-40 PetaFlops Peak Performance (Next Generation Xeon processors)
- ▶ Interconnect: Mellanox HDR and HDR-100 links.
  - ▶ Fat Tree topology, 200Gb/s links between switches.
- ▶ Storage: DataDirect Networks
  - ▶ 50+ PB disk, 3PB of Flash, 1.5TB/sec peak I/O rate.
- ▶ Single Precision Compute Subsystem: Nvidia
- ▶ Front end for data movers, workflow, API



# SYSTEM OVERVIEW





- ▶ **Humphry Davy, Inventor of Electrochemistry, 1812**
- ▶ (Pretty sure he was talking about our machine).

Nothing tends so much to the advancement of knowledge as the application of a new instrument. The native intellectual powers of men in different times are not so much the causes of the different success of their labours, as the peculiar nature of the means and artificial resources in their possession.

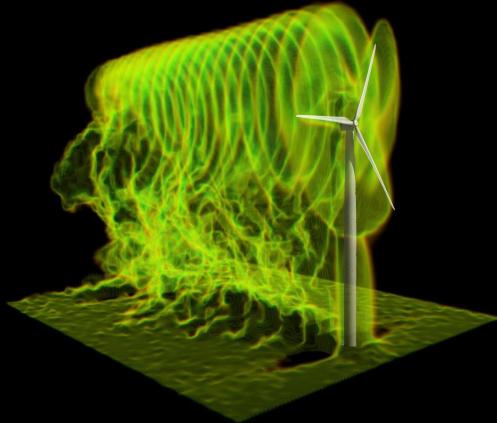
Humphry Davy

PICTUREQUOTES . com

# REAPING POWER FROM WIND FARMS

## Multi-Scale Model of Wind Turbines

- Optimized control algorithm improves design choices
- New high-res models add nacelle and tower effects
- Blind comparisons to wind tunnel data demonstrate dramatic improvements in accuracy
- Potential to increase power by 6-7% (\$600m/yr nationwide)



"TACC...give[s] us a competitive advantage..."

Graphic from Wind Energy, 2017.

Christian Santoni, Kenneth Carrasquillo,  
Isnardo Arenas-Navarro, and Stefano Leonardi

UT Dallas, US/European collaboration (UTRC, NSF-PIRE 1243482)

[TACC Press Release](#)

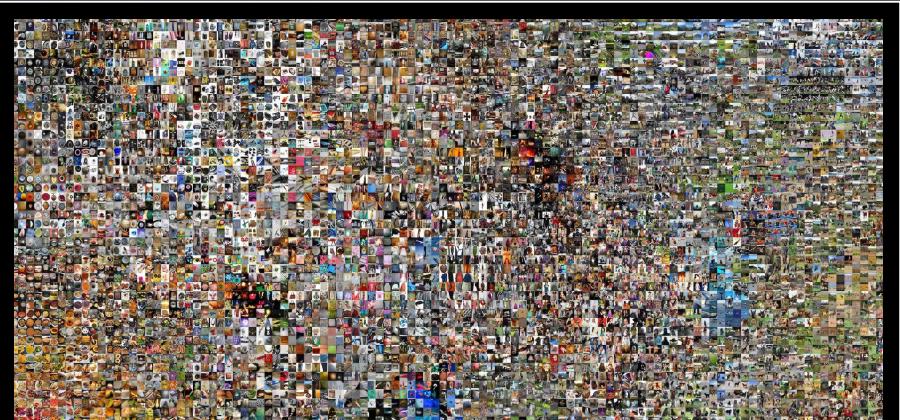
*"Using commodity HPC servers...the time to data-driven discovery is reduced and overall efficiency can be significantly increased." (Niall Gaffney, TACC)*

## RECORD ACHIEVED ON AI BENCHMARK

TACC, Berkeley, Cal Davis collaborate  
on large-scale AI runs

- Research demonstrating the potential of commodity hardware for AI
- Skylake ImageNet benchmark: (100 epochs, 11 min, 1024 nodes) -- fastest result at time of publication
- Knights Landing ImageNet benchmark (90 epochs, 20 min, 2048 nodes) – 3x faster than Facebook, with higher large-batch accuracy

Graphic credit Andrej Karpathy



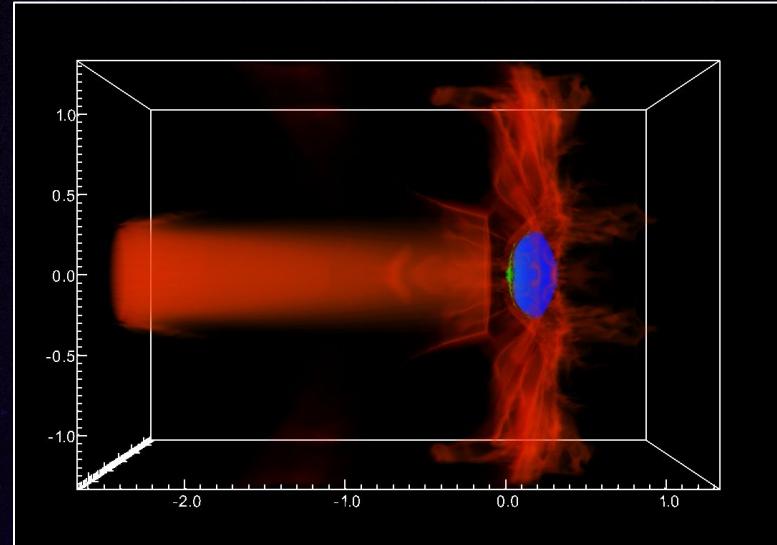
Yang You, Zhao Zhang, Cho-Jui Hsieh, James Demmel, Kurt Keutzer

[TACC Press Release](#)

# USING KNL TO PROBE SPACE ODDITIES

Ongoing XSEDE collaboration focusing on KNL performance for new, high-resolution version of COSMOS MHD code

- Vectorization and other serial optimizations improved KNL performance by 50%
- COSMOS currently running 60% faster on KNL than Stampede1
- Work on OpenMP-MPI hybrid optimizations now underway
- Impact of performance improvements amounts to millions of core-hours saved



"The science that I do wouldn't be possible without resources like [Stampede2]...resources that certainly a small institution like mine could never support. The fact that we have these national-level resources enables a huge amount of science that just wouldn't get done otherwise." (Chris Fragile)

XSEDE ECSS: Collaboration between PI Chris Fragile (College of Charleston) and Damon McDougall (TACC)

[TACC Press Release](#)

# MASSIVE DATA SET WORTHY OF ROSS ICE SHELF ITSELF

TACC partners with Lamont-Doherty Earth Observatory (LDEO) to host for one of the country's largest earth sciences data collections

- Managing hundreds of TB using Stampede2, Corral, and Ranch: storage, provenance, visualization, and public access
- Achieved 10x workflow speedup by moving to TACC (from 50 hrs down to 5 hrs for transfer and analysis tasks)



*“...partnership...with TACC shows [it’s] possible to manage...this level of data in a cost-effective, user-friendly and easily accessible manner...”*

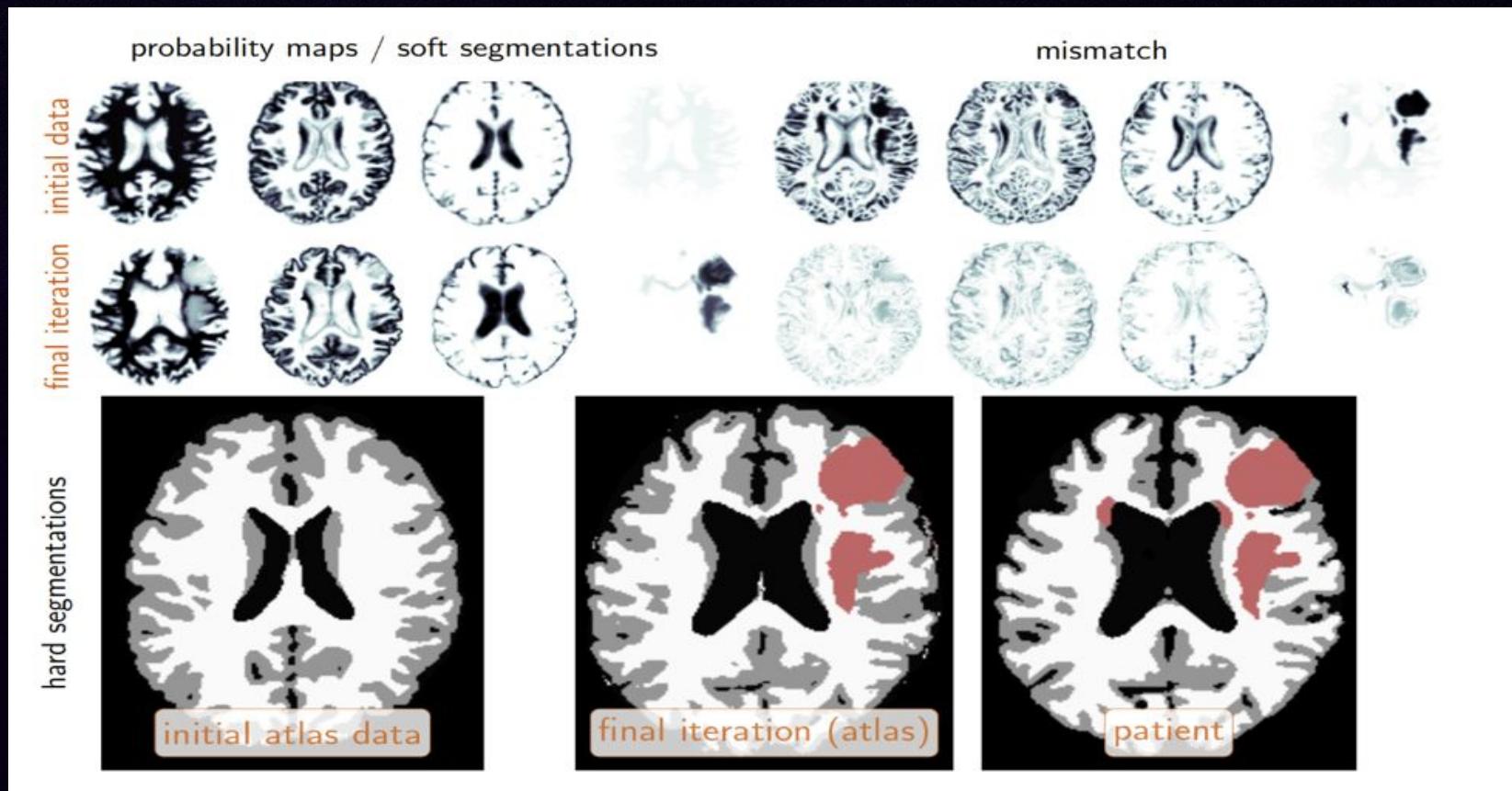
Image courtesy Oceanwide Expeditions.

[TACC Press Release](#)

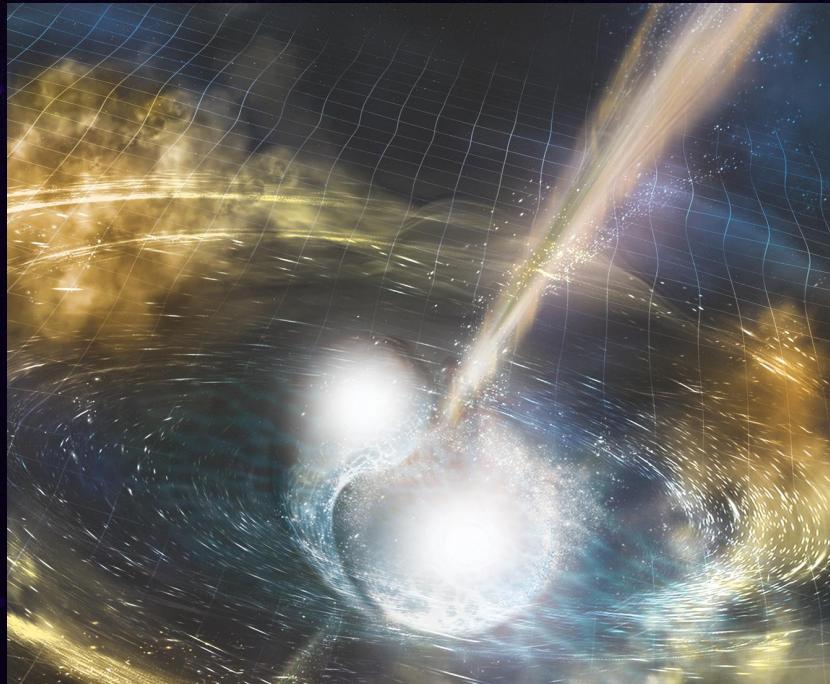
PI Lingling Dong, Columbia University  
XSEDE support to multidisciplinary, multi-institutional Rosetta project

# BRAIN TUMOR SEGMENTATION

- ▶ A team of researchers led by George Biros from The University of Texas at Austin scored in the top 25% of participants in the Multimodal Brain Tumor Segmentation Challenge 2017 (BRaTS'17) enabled by Stampede2 and other TACC resources.
- ▶ In the challenge, research groups presented methods and results of computer-aided identification and classification of brain tumors, as well as different types of cancerous regions.
- ▶ The team's method combined biophysical models of tumor growth with machine learning algorithms for the analysis of Magnetic Resonance imaging data of glioma patients.



# The Laser Interferometer Gravitational-Wave Observatory (LIGO)



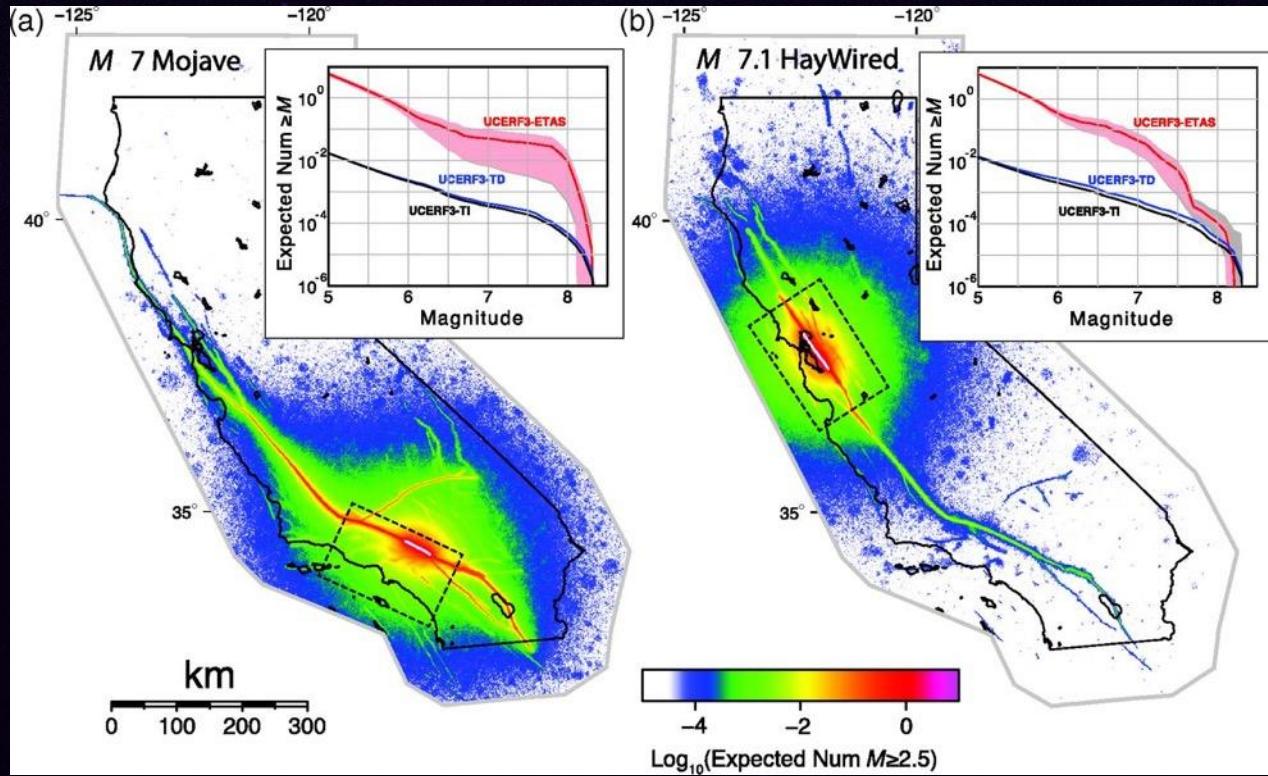
- ▶ TACC provided consulting services to LIGO researchers, 10x improvement in runtime
- ▶ seven million core hours on Stampede to help analyze the first detected gravitational

"Stampede was an excellent tool for improving our understanding of the universe we live in, from the smallest scale of sub-atomic particles to detecting gravitational waves that have traveled a million light-years to the earth, and a lot of exciting science and engineering in between"

Stuart Anderson, Caltech  
LIGO Research Manager



# AFTERSHOCK FORECASTING



# SOLAR CORONA PREDICTION

Polarized Brightness (Newkirk Filter)

Log Polarized Brightness (Unsharp Masked)



PSI Prediction 08/14/2017 - Terrestrial North up

PSI Prediction 08/14/2017 - Terrestrial North up

- ▶ Predictive Science, Inc. (California)
- ▶ Supporting NASA Solar Dynamics Observatory (SDO)
- ▶ Predicted solar corona on S2 during 8/21/17 eclipse



# COSMOS GRAVITATIONAL WAVES STUDY

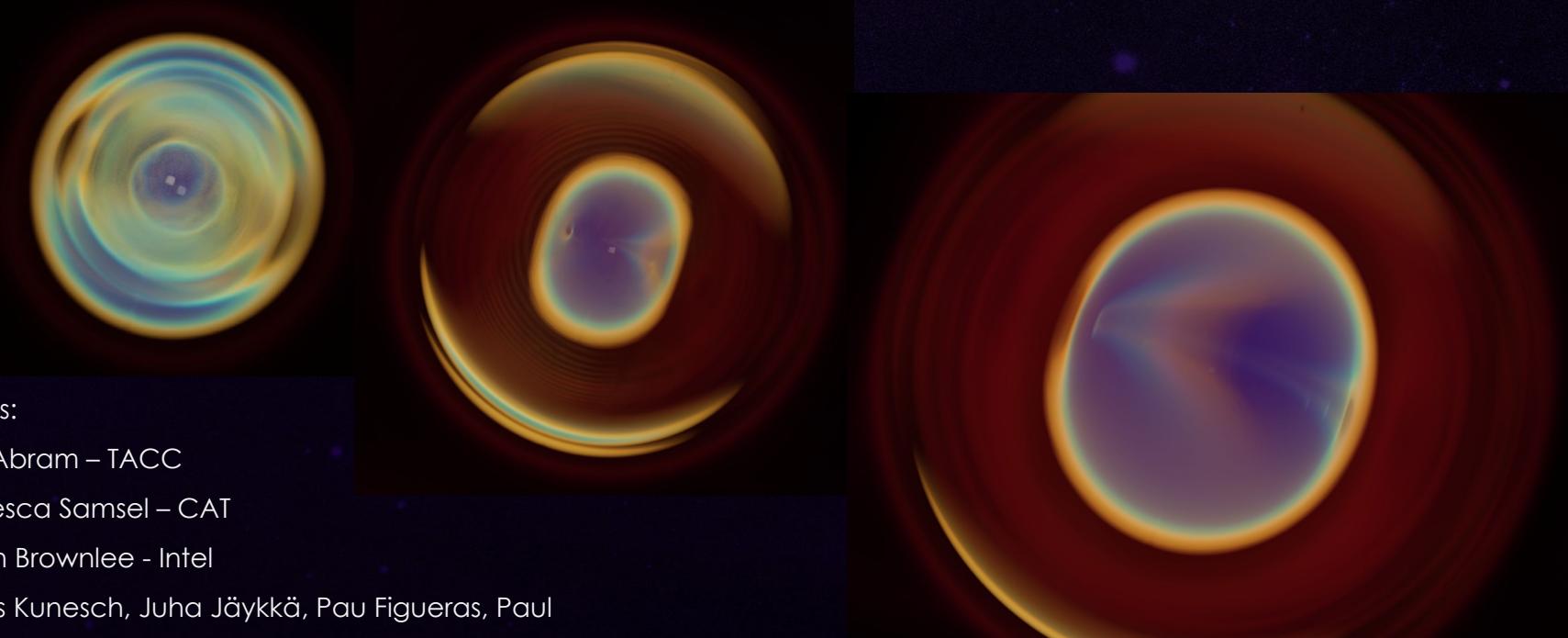


Image Credits:

Greg Abram – TACC

Francesca Samsel – CAT

Carson Brownlee - Intel

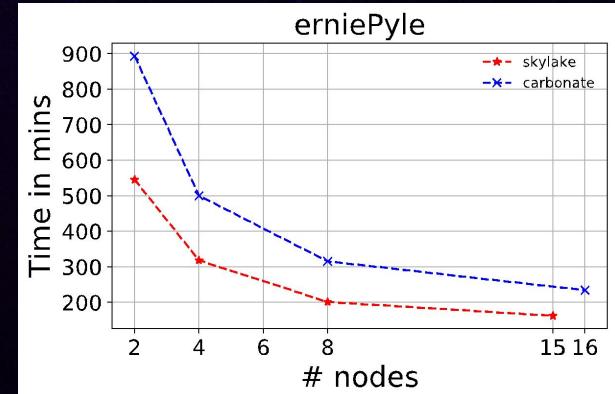
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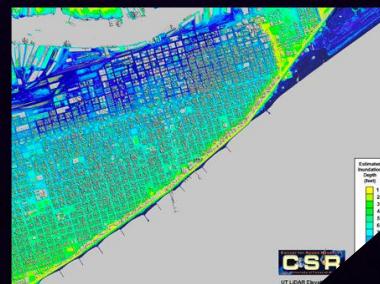
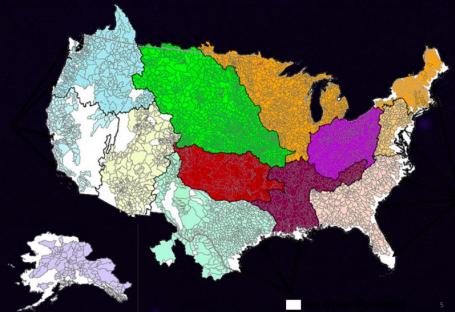
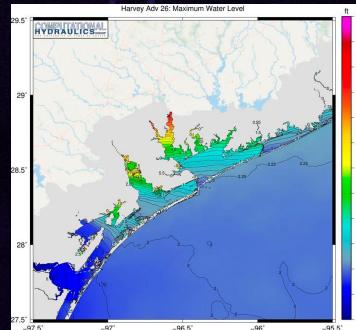
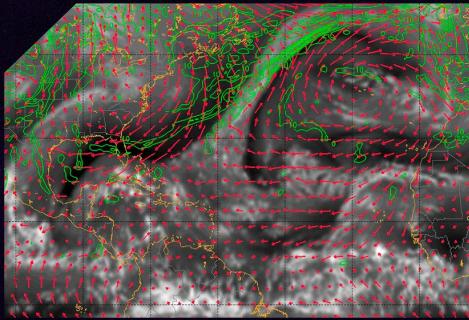
Center for Theoretical Cosmology, University of Cambridge



# PHOTOGRAMMETRY ON KNL

- ▶ Effort lead by IU (Wernert, McCombs, Ruan, Tuna)
- ▶ Create 3d point cloud & Mesh Model of texture/color map using tiled 2d images
  - ▶ Camera panoramas, Drone Survey
  - ▶ Future underwater shipwrecks/reefs
- ▶ Using Agisoft Photoscan software
  - ▶ More speedup from larger datasets
- ▶ Exploring OpenSource alternatives
  - ▶ Adding MPI layers needed





## HARVEY

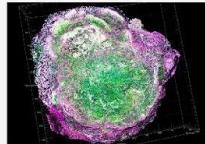
- ▶ Next Generation Storm Forecasting (with Penn State)
- ▶ Storm Surge Modeling (with Clint Dawson UT Austin)
- ▶ Preliminary river flooding and inundation maps (David Maidment UT Austin)
- ▶ Remote Image Integration and Assimilation (Center for Space Research, UT Austin)

**The Texas Advanced Computing Center accelerates basic and applied cancer research to help save lives.**

*fighting*

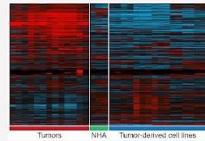
#### **Computer Modeling**

Researchers use advanced computing to model tissues, cells and drug interactions, and to design patient-specific treatments and identify new medicines.



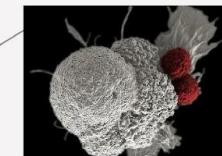
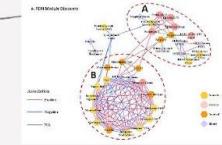
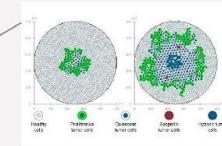
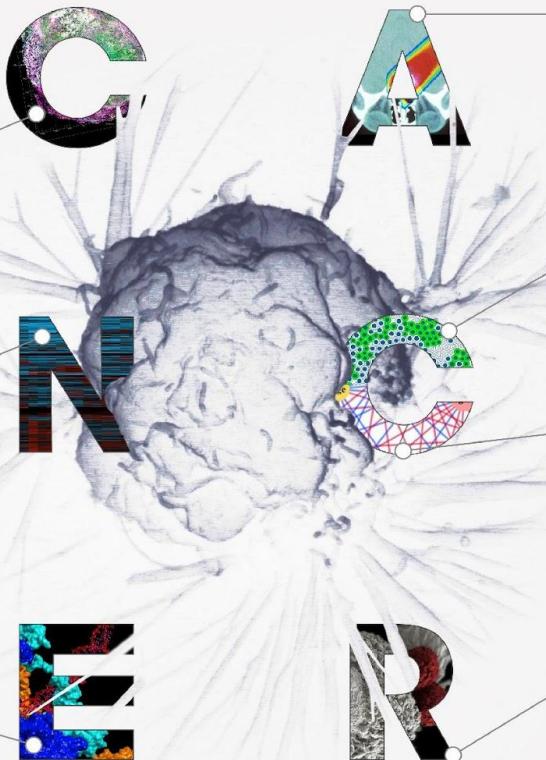
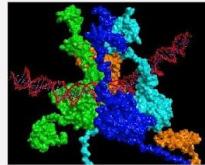
#### **Big Data Analysis**

Supercomputers allow researchers to find patterns in genomes and among patient outcomes to pinpoint risks and target treatments.



#### **Molecular Dynamics Simulations**

Simulating protein and drug interactions at the atomic level enables scientists to understand cancer and design more effective therapies.



#### **Quantum Calculations**

Exploring how proton and x-ray beams interact with DNA on the quantum level helps explain why radiation treatments work and how they can be optimized.

#### **Trial Design**

Researchers use TACC's advanced computers to design clinical trials that can determine the combination of dosages that will be most effective.

#### **Clinical Planning**

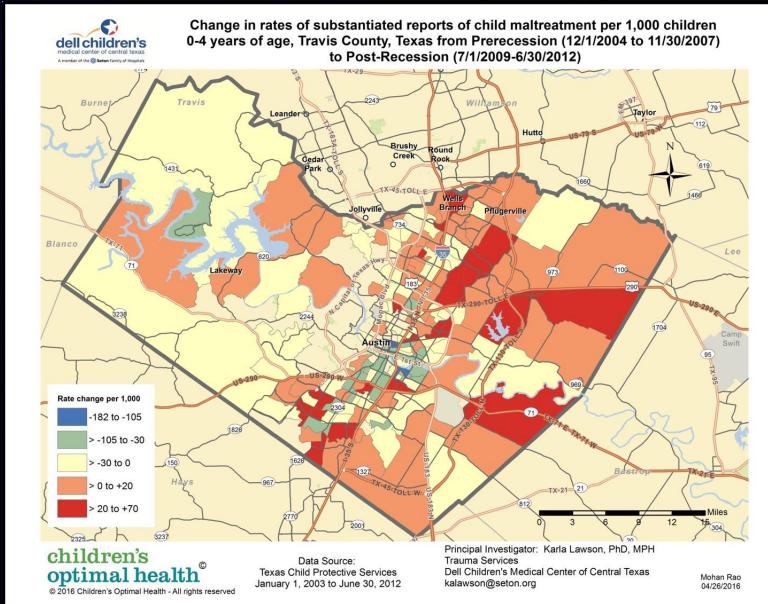
Supercomputers can test thousands of potential treatments in advance to help decide which one will work best.

#### **Artificial Intelligence**

AI on high-performance computers can uncover relationships among complex cellular networks and reverse-engineer interventions.

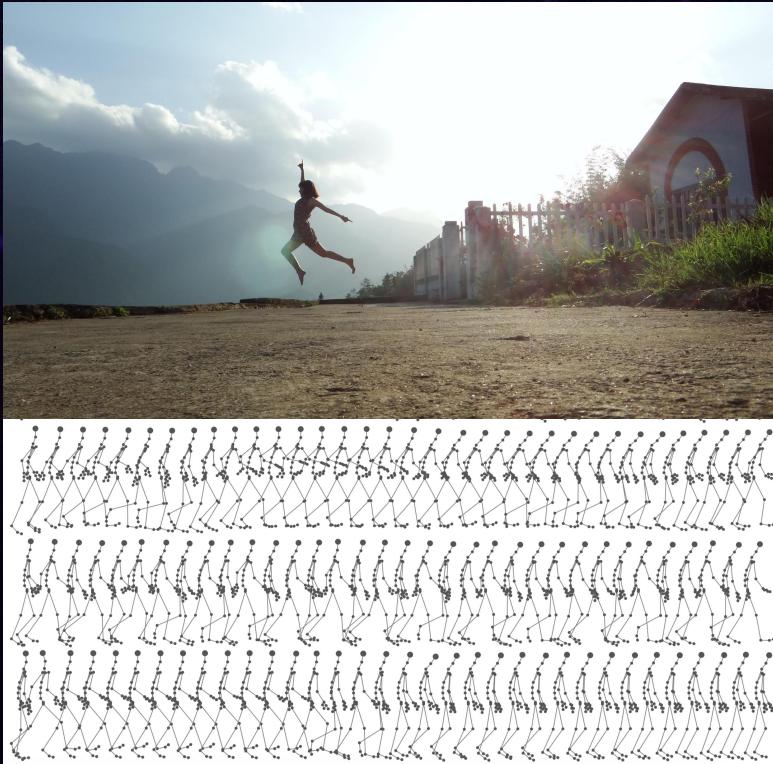
*— with supercomputers —*

# IMPROVE CHILD WELFARE THROUGH ADVANCED COMPUTING



The Texas Advanced Computing Center (TACC) at The University of Texas at Austin has teamed up with Austin, Texas-based non-profit Children's Optimal Health (COH) to provide the technical infrastructure needed to help solve issues in children's health and education throughout Central Texas, including disease, mental health and adverse childhood experiences.

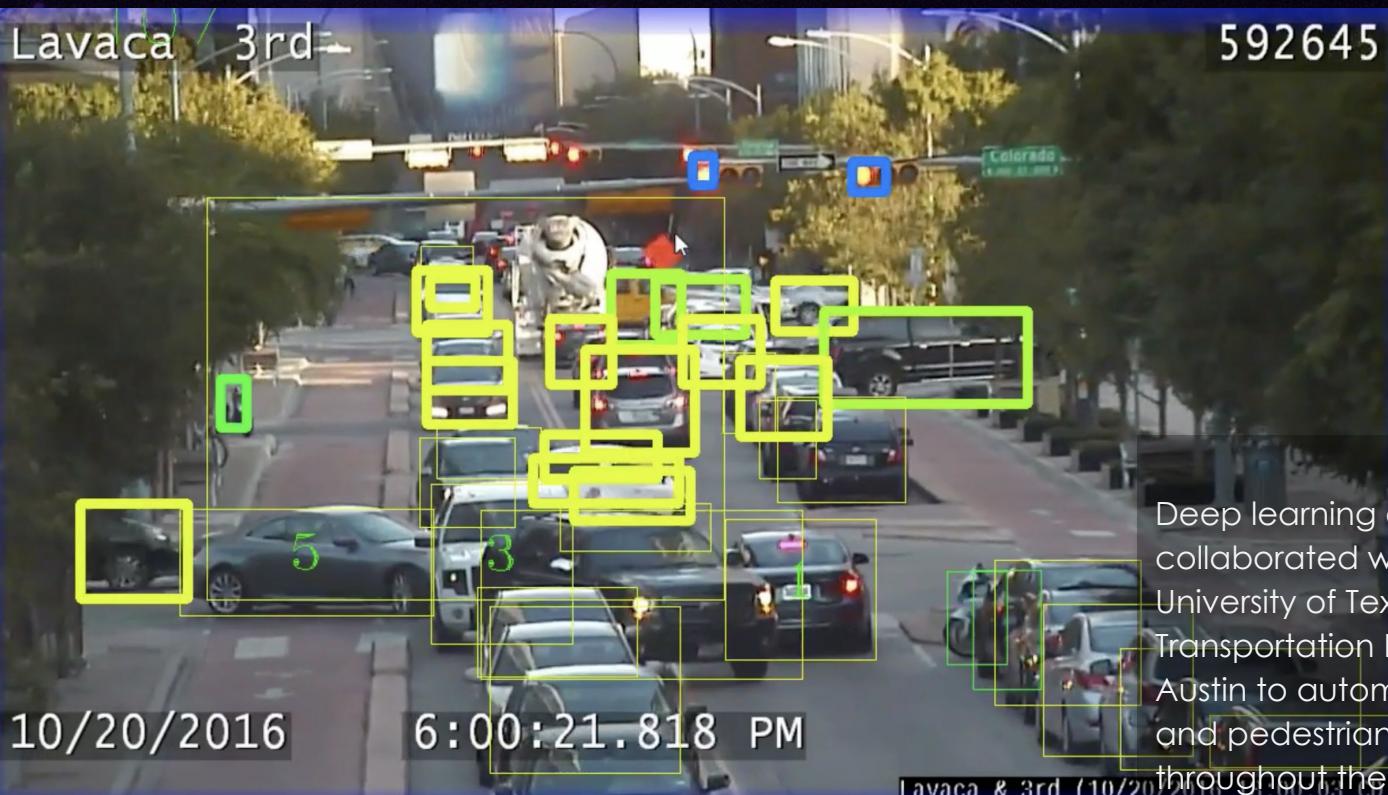
# A DANCE WITH ALGORITHMS



- ▶ XSEDE resources help researchers merge art and science to create systems that can understand and produce human-quality movement
- ▶ Uses deep learning techniques and relies on the collaboration of graduate students with artists to create new algorithms
- ▶ *On a single computer, running our algorithms would take years, on medium-sized resources months, but using XSEDE, we can train some of most complex models within 24 hours.* - Philippe Pasquier, professor and researcher, Simon Fraser University

Lavaca / 3rd

592645



10/20/2016

6:00:21.818 PM

Lavaca & 3rd (10/20/2016 6:00:03 CB)



Deep learning experts from TACC collaborated with researchers at the University of Texas Center for Transportation Research and the City of Austin to automatically detect vehicles and pedestrians at critical intersections throughout the city using machine learning and video image analysis. [Credit: Weijia Xu, TACC]



**Background:** The COVID-19 pandemic required a rapid response to provide forecasting models to key decision makers. The COVID-19 Science Gateway is part of The University of Texas at Austin COVID-19 Modeling Consortium

**Objective:** Provides decision-makers with key predictive models necessary. Enables researchers to run models easily through the science gateway.

**Results:** Within a week the team launched an official consortium gateway, allowing people across the country to access projections about mortality rates within different states and metropolitan areas. Used by CDC, White House, local policy makers. Over 400K visits from 180+ countries. Featured on CNN, New York Times. Additional external funding of \$389,400 has been identified by the client.



The University of Texas at Austin  
**COVID-19**  
Modeling Consortium

PROJECTIONS PUBLICATIONS PEOPLE

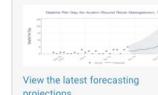


## UT Austin COVID-19 Modeling Consortium

An interdisciplinary network of researchers and health professionals building models to detect, project, and combat COVID-19

[View the latest COVID-19 Projections](#)

Interactive COVID-19  
Projections Tool



COVID-19 Publications



### COVID-19 Modeling Consortium News

Hoping for a COVID-19 antiviral that limits virus spread

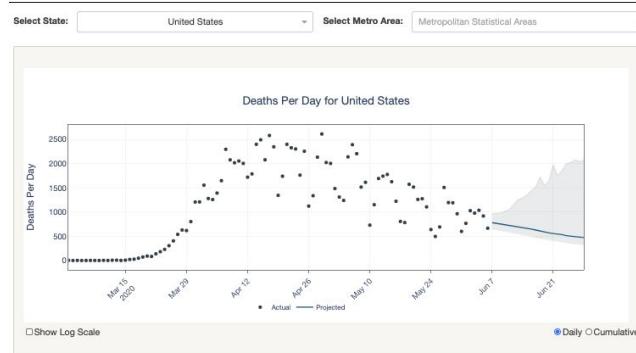
As the COVID-19 pandemic claims hundreds of thousands of lives and wreaks economic havoc worldwide, scientists are racing to develop antivirals that reduce the fatality of the disease. [LEARN MORE](#)

# The University of Texas COVID-19 Modeling Consortium

## COVID-19 Mortality Projections for US States

These graphs show both the reported and projected number of COVID-19 deaths per day across the US and for individual states. We use local data from mobile-phone GPS traces to quantify the changing impact of social-distancing measures on "flattening the curve." Code syntax and daily updates of our forecasts are available on our UT-COVID GitHub repository.

Select your area in the dropdown menu below



\* Click and drag on the plot to zoom-in and double-click to zoom-out completely. The icons at the top right of each graph will provide you with additional options.

Note: On May 7, 2020 we switched to using data on confirmed and probable COVID-19 deaths to make forecasts, rather than only confirmed deaths.

Key model assumptions: The model estimates the extent of social distancing using geolocation data from mobile phones and assumes that the extent of social distancing does not change during the period of forecasting. On June 2, 2020 we started reporting an ensemble forecast, combining predictions from our original model based on "curve-fitting" and a new SEIR based model.



# GOOGLE COLAB



<https://colab.research.google.com/>



# CODE@MS-CC Day 1

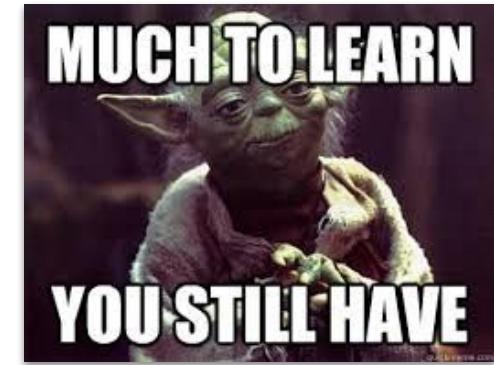
Let's do this!

PRESENTED BY:

# Computational Thinking Objectives

The student will ...

- Learn the about the concept of “computational thinking”
- Practice algorithm implementation through abstraction
- Learn about the concept of pseudo code
- Apply computational thinking to the equation for a straight line



# Back when mathematicians were computers and computers were calculators...

- Initially all programming was dedicated to translating math formulas.
- The work lead to the language FORmula TRANslator.



# **“Computational Thinking is the translation of ideas into computer code” ~Victor Eijkhout**

## **Mathematical Thinking**

- Number of people an elevator takes per day
- Speed (velocity) of an elevator
- Distribution of people in an elevator

## **Computational Thinking**

- If there are X # of people expected to use elevators, how many should be installed?
- If someone at floor 0 presses the call button and there are available cars on floors 5 and 9, which car should respond?



# **The Process of Forming Logic (Think teaching a 3 year-old)**

How would you tell a three(3) year old family member to get your keys out of the drawer in your room ?



# Requirements, Logic, Algorithms, and Parameters

**Requirements** - what elements are needed before the job can be taken on

**Logic** - a system or set of principles underlying the arrangements of elements in a computer or electronic device so as to perform a specified task [an order in which to do a task]

**Algorithm** - a process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer [logic + calculations = algorithm]

**Parameters** - a limit or boundary that defines the scope of a particular process or activity [limits set on an algorithm = parameters]

# Making a PB&J Sandwich

**Requirements** - what elements are needed before the job can be taken on

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# Finding a definition in a dictionary

**Requirements** - what elements are needed before the job can be taken on

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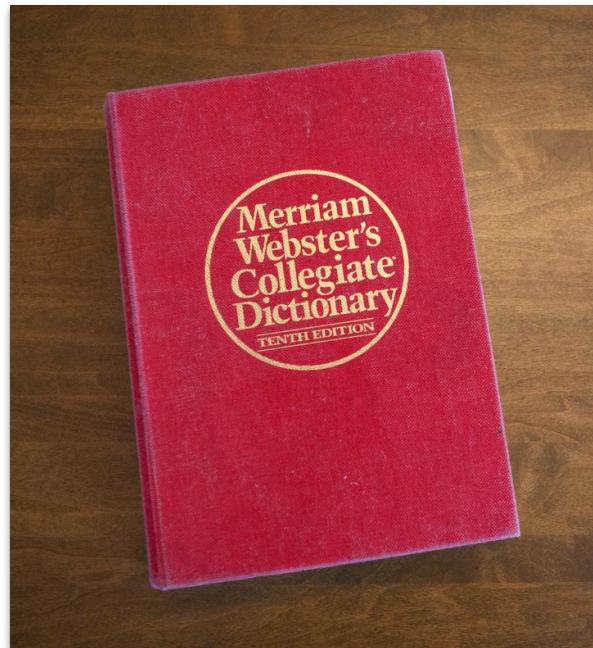
## Given (Input):

- Dictionary
- Word (string)

## Find (Output):

- Definition

*Define your algorithm*



# Sorting

**Requirements** - what elements are needed before the job can be taken on

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**Given:**

A bag of potatoes



**Problem:**

Sort the bag of potatoes  
from smallest to largest

**Algorithm:????**



# Think outside the "Box"

**Requirements** - what elements are needed before the job can be taken on

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**Logic** - a system or set of principles underlying the arrangements of elements in a computer or electronic device so as to perform a specified task [an order in which to do a task]

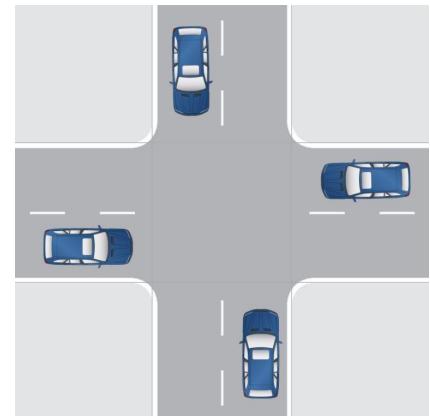
**Algorithm** - a process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer [logic + calculations = algorithm]

## Problem:

4 automated cars come to an intersection at the same time.

Who goes first?

Algorithm: ???



45

# What decisions did you make?

**Requirements** - what elements are needed before the job can be taken on

**Parameters** - a limit or boundary that defines the scope of a particular process or activity [limits set on an algorithm = parameters]

**Logic** - a system or set of principles underlying the arrangements of elements in a computer or electronic device so as to perform a specified task [an order in which to do a task]

**Algorithm** - a process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer [logic + calculations = algorithm]

What was the last meal you ate?

What were the defining parameters on why you chose that meal?

# Where do we go? Where do we go now?

Look at each problem you are going to tackle, and figure out the requirements - what is needed to solve? Figure out the logic on how to solve it, and apply the algorithm.



# Think about a Scientific Process

Let's meet Joe.

Joe might get sick.

Joe will be sick for 5 days.

After 5 days, Joe gets better.

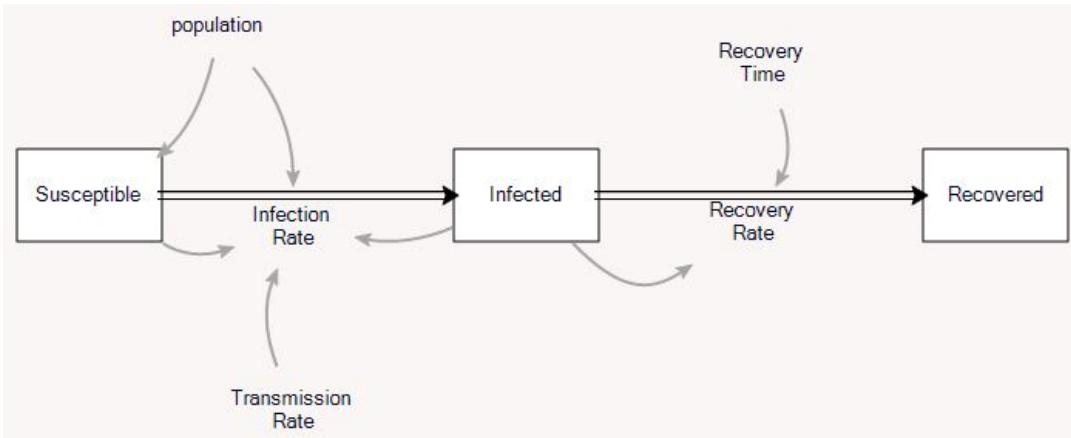
Once Joe gets better, Joe can no longer get sick.

How would we "code" Joe?

## "Hi I'm Joe"



# The SIR Model



# \*\*\*Task 1\*\*\* - Code Joe

**Variables** to hold data

**Mathematical Operations** to do math :)

**Conditionals** to make decisions

**Loops** to repeat our process

**Functions/Subroutines** to reuse code

**Objects or Classes** to define our "things"

Let's meet Joe.

Joe might get sick.

Joe will be sick for 5 days.

After 5 days, Joe gets better.

Once Joe gets better, Joe can no longer get sick.



50

Let's "code" Joe.

## **\*\*\*Task 2\*\*\* Code Joe and Jane**

We met Joe.

Joe has a friend, Jane

If Joe gets sick, Jane might get sick.

Modify your code, so when Joe gets sick that triggers Jane to roll a random number to see if Jane gets sick.

Loop through your code until both Joe and Jane get sick and they each get better.

**"Hi I'm Jane and I  
unfortunately  
know Joe"**



# *Object Oriented Python*

## What's an Object?

Object-oriented programming is a programming paradigm that provides a means of structuring programs so that properties and behaviors are bundled into individual objects.

Hackathon Attendees and Je'amime (and me): "HUH?!"



# *Object Oriented Python*

What's an Object? - Let's try this again

Object-oriented programming allows you to code up "things" that have *properties/attributes* (variables) and *behaviors/methods* (functions)

These "things" allow us to create reusable code and allows us mimic real "things"

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# *Object Oriented Python*

How do we go about doing this?

## Classes

A class is a blueprint for how something should be defined.

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## Classes

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Let's design our ***Person Class***

# *Object Oriented Python*

We need another concept.

the *instance*?

The class is the blueprint, an *instance* is an object that is built from a class and contains real data.

The **class** would be a form, the **instance** is the form filled out.

# *Object Oriented Python*

We need a couple bits of syntax.

**the *self***

The ***self*** parameter is a reference to the current *instance* of the class, and is used to access variables that belongs to the class.

# *Object Oriented Python*

We need a couple bits of syntax.

## **the `__init__`**

When you create a new object of a class, Python automatically calls the `__init__()` method to initialize the object's attributes.

## \*\*\*Task 2\*\*\* Code Joe and Jane

We met Joe.

Joe has a friend, Jane

If Joe gets sick, Jane might get sick.

Modify your code, so when Joe gets sick that triggers Jane to roll a random number to see if Jane gets sick.

Loop through your code until both Joe and Jane get sick and they each get better.

