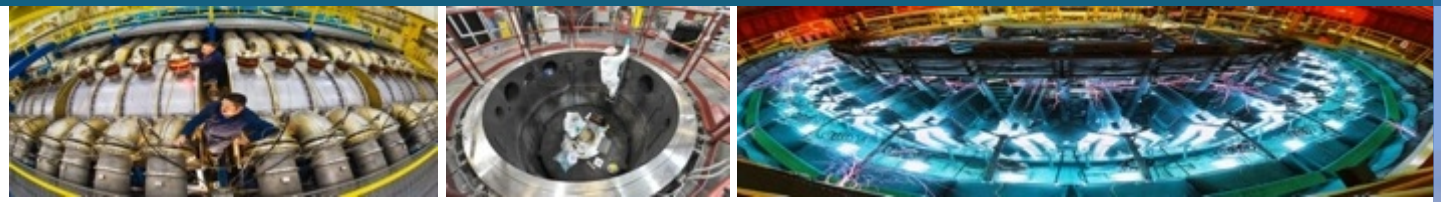
Sandia National Laboratories

AMPPD: Bringing modern Data Science and Machine Learning methods to HED Science



2021 REHEDS External Review

Patrick Knapp

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

AMPPD emerged from a grass roots effort to improve our ability to infer the stagnation pressure in MagLIF experiments

For 10 years I have been a PI on Z experiments studying ICF and HED science. In 2016 I was searching for a better way to measure the stagnation pressure

The old way:

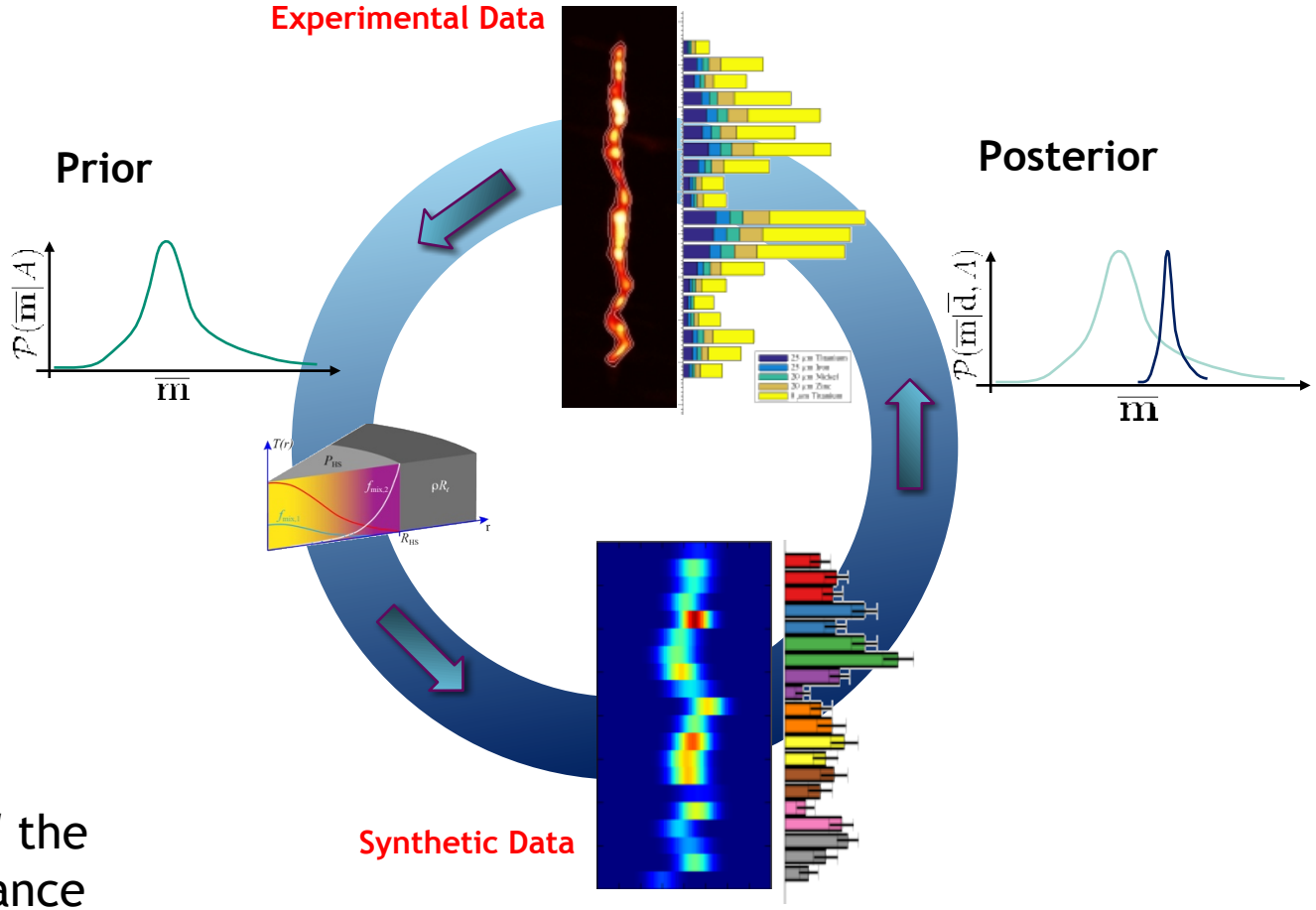
$$P_{\mathrm{HS}} = (1 + \langle Z \rangle)\sqrt{\frac{2Y_{\mathrm{DD}}}{V \tau_b S(T)}}$$

Mix?

Volume?

time?

temperature?



With Michael Glinsky's help, we developed a Bayesian inference method that leverages *all* the data to simultaneously infer critical performance quantities with quantified uncertainty

This technique has allowed us infer stagnation pressure and mix fraction leveraging all available diagnostics[1]

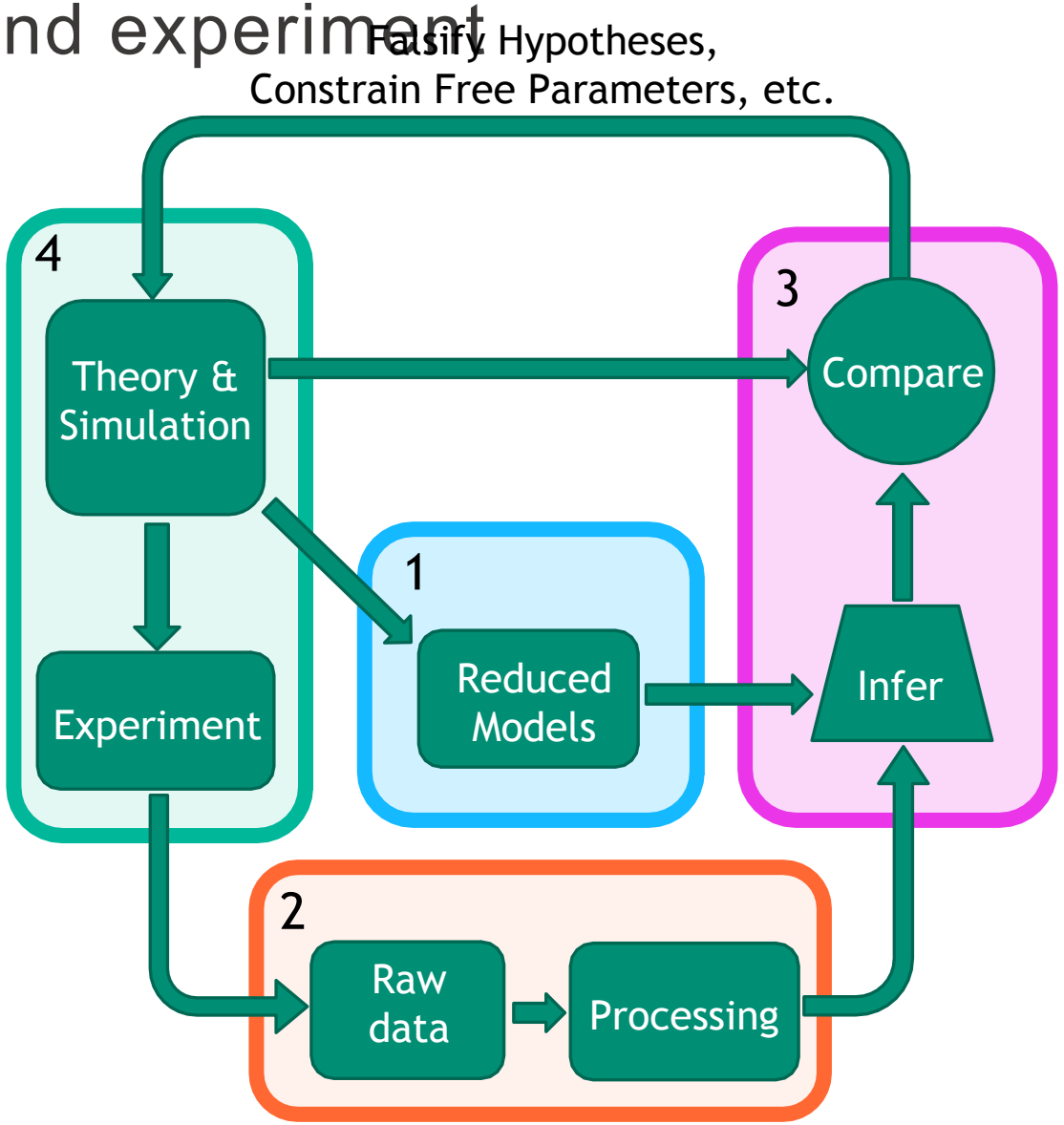
1) P.F. Knapp et al., Phys. Plasmas, 26, 012704 (2019)

The AMPPD working group's goal is to to advance our understanding of HED systems utilizing a seamless integration of theory, modeling, and experiment

Algorithms and Models for Pulsed Power Data (AMPPD) is a multidisciplinary group with REHEDS, CIS, and external members

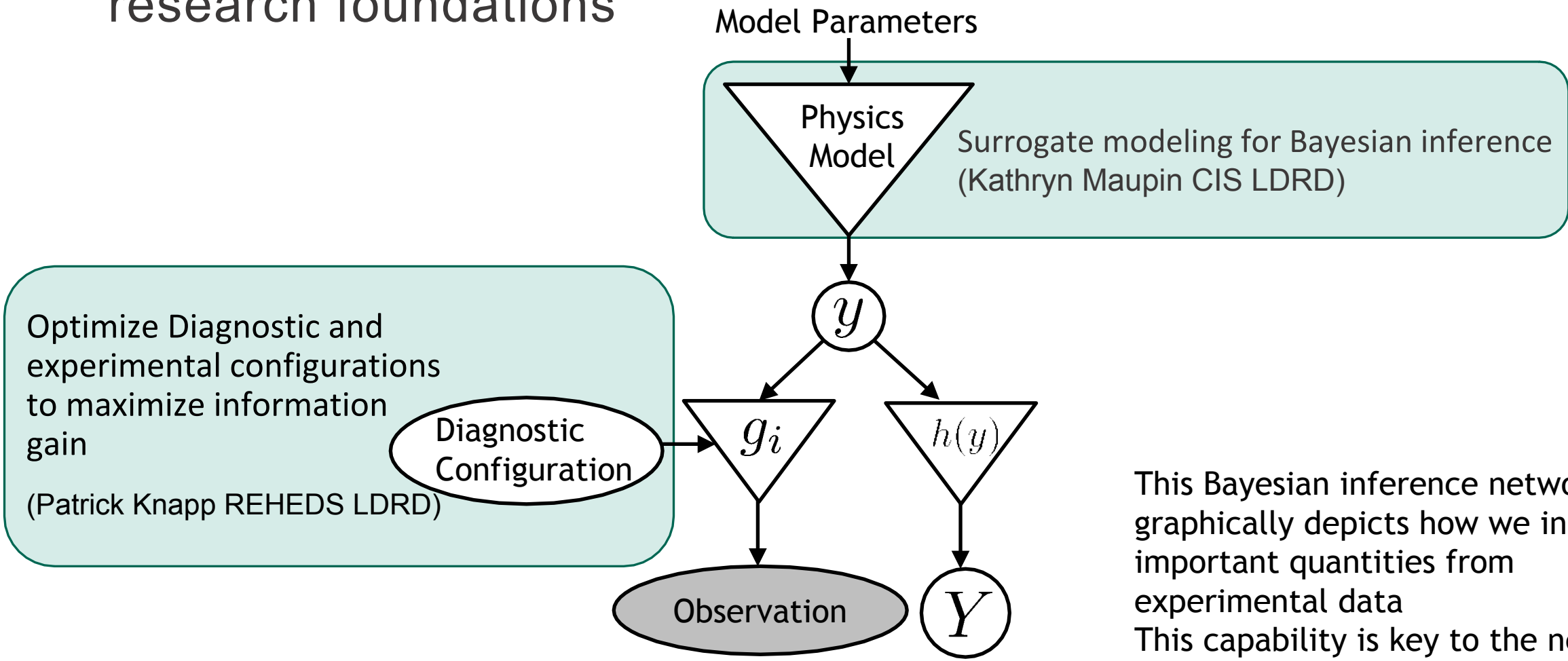
How do we traditionally do experiment design, data analysis and integration with theory?

- Small model explorations to scope hypotheses and look at sensitivities
- Design experiments for large changes in outcomes so that qualitative results can steer future directions
- Labor intensive manual data reduction with no UQ
- Labor intensive manual data analysis with little to no UQ
- Compare reduced data outputs to simulation outputs, adjust modeling practices and/or update mental map of "dragons" to avoid in parameter space



https://cee-gitlab.sandia.gov/amppd

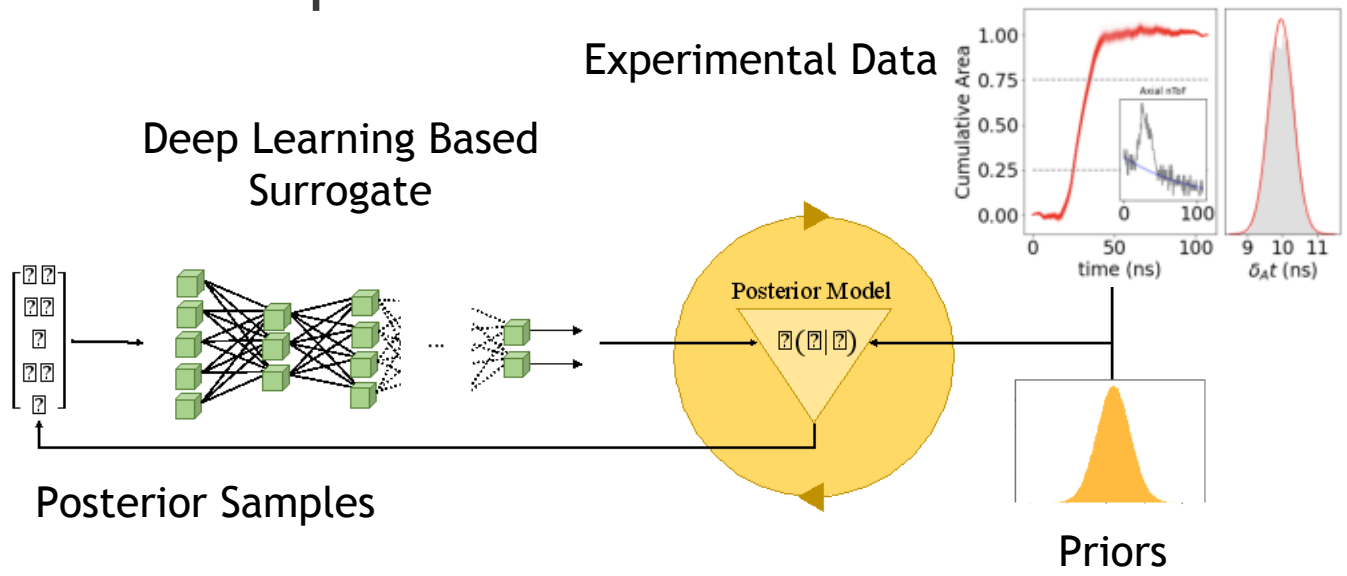
AMPPD Provides a venue for multiple independent projects to interact and leverage resources across research foundations



This Bayesian inference network graphically depicts how we infer important quantities from experimental data
This capability is key to the near- and mid-term ICF and HEDP program goals

Both LDRD's are in their first year, and both are leveraging collaborations with world leading experts at GA Tech.

Combining Deep Learning with Bayesian inference allows us to efficiently analyze data that would have previously been impossible



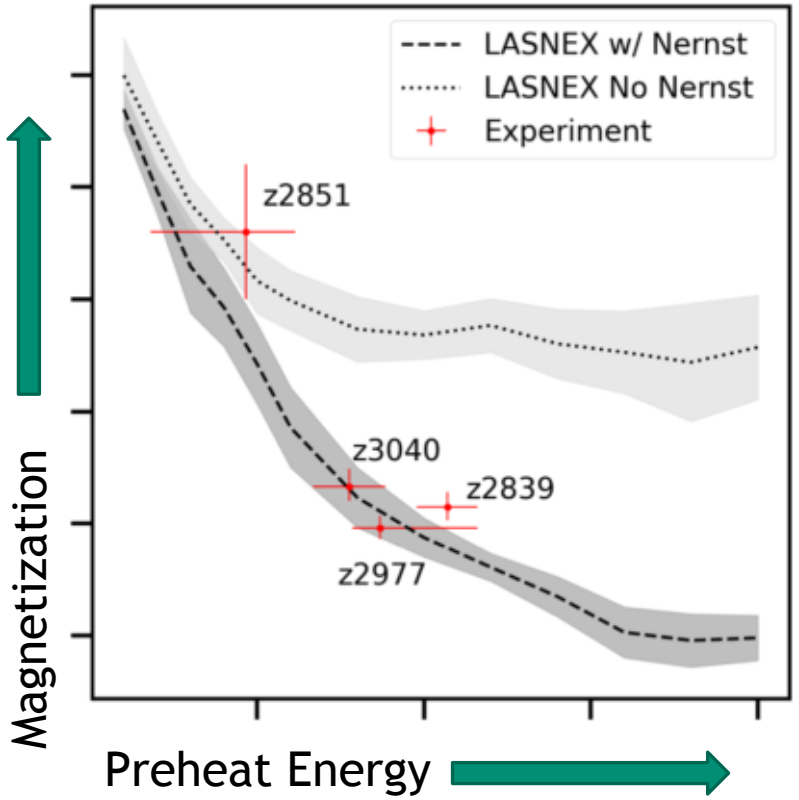
An expensive physics model is the basis of BR inference[2,3]

- 1 Evaluation in ~10-100 CPU hours

We created a deep-learned surrogate of this model

- 1 Evaluation in ~1 ms on a laptop

MCMC requires ~10k model evaluations, providing us with inferred values and credible intervals



This technique is being used to study the consequences of the Nernst effect in MagLIF implosions

Work by Will Lewis, Accepted in Phys. Plas

2) P.F. Schmit et al., PRL 113, 155004 (2014)
3) P.F. Knapp et al., Phys. Plasmas, **22**, 056312 (2015)

We are building the foundations that will allow us to fully utilize experimental data to constrain and improve our models

FY25 ICF objectives rely heavily on tools enabled by these techniques

- Analyzing 3D data and comparing to simulation
- Inferring ICF scaling & performance metrics from experimental data

Current projects are supporting post-docs, interns, and early-career staff, helping to develop a lasting workforce in this area

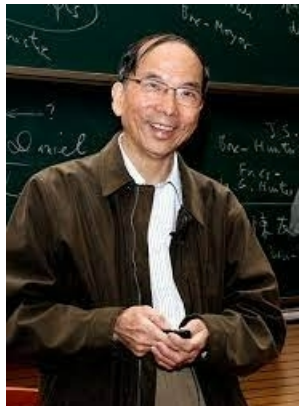
engaged the external community (e.g. Google, MSU, GA Tech., etc.)

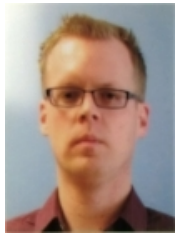
In conjunction with LLNL and several academic partners we are planning a future workshop and an educational mini-workshop to develop students and young scientists

Georgia Tech

Roshan Joseph

Jeff Wu





Marc Schaeuble

Jeff Fein

MICHIGAN STATE UNIVERSITY

Gina Vasey

UNIVERSITY of ROCHESTER

James Young

Will Lewis

Kathryn Maupin

Ravi Patel