Machine Learning Aided Discovery of a New NIF Design

DSI/ UC Data Science Workshop

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August 7, 2018

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory
under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

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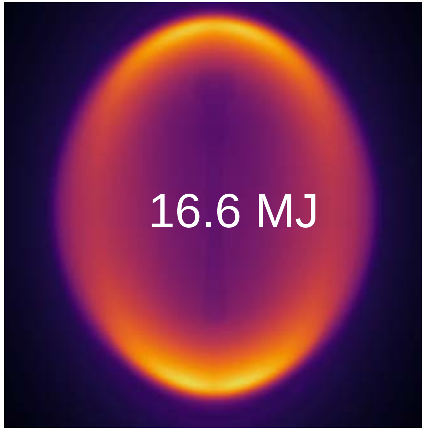
- Scott Brandon
  - UQPipeline Team
- Ryan Nora
- Steve Langer
- Joe Koning
  - HYDRA Team
- Dave Munro
- Jim Gaffney
- Michael Kruse
- Michael Buchoff
- Jim Hammer
- Paul Springer
- ICF HDC Team
  - D. Ho & L. Berzak Hopkins
- Luc Peterson
- Kelli Humbird (TAMU)

We have discovered a new kind of robust Inertial Confinement Fusion implosion

- Suggested by an AI system (Random Forest) trained on the largest ICF simulation dataset ever created
  - Trinity Open Science Phase I (LANL)
- Optimal implosion is an ovoid, not sphere, challenging known physics
- Presence confirmed by new simulations not in the original dataset – digging into "why"
- We are building tech to enable these kinds of discoveries



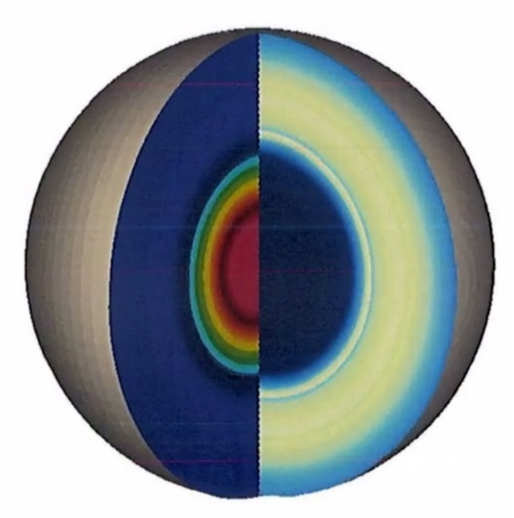
Density at Bang Time

J. L. Peterson, et al.,
Physics of Plasmas, **24**(3):032702 (2017)

Machine learning on a large ensemble of simulations has pointed to a new class of robust implosions

Fall 2015: Can we make NIF Designs more resilient?

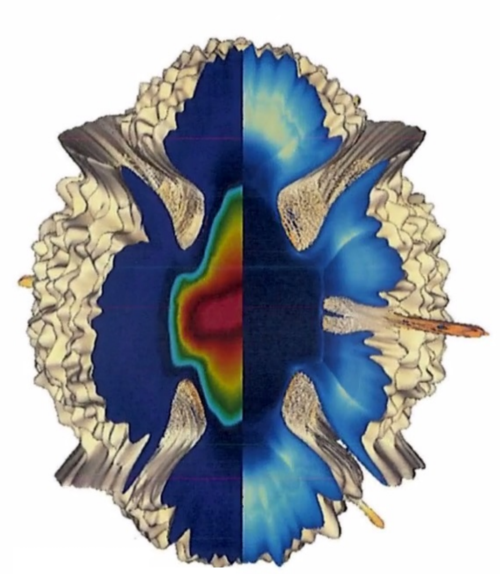
We want this



D. Clark

Fall 2015: Can we make NIF Designs more resilient?

But can get this



Can we withstand these kinds of imperfections?

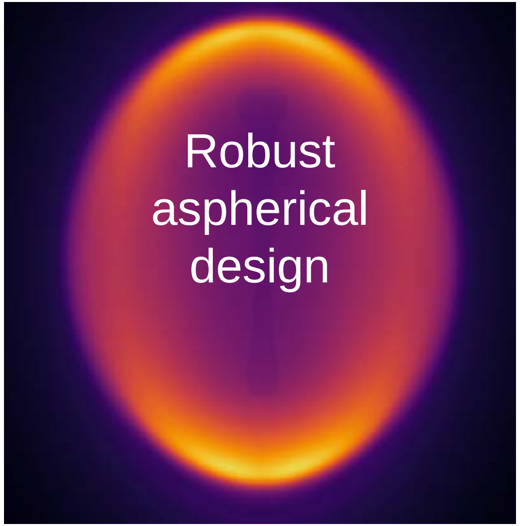
D. Clark

Machine Learning said yes! But the results were unexpected

Machine learning helped uncover an unexpected, robust NIF ICF capsule design

- Enabled by large-scale HPC ensemble simulation
- Post-facto learning on processed results
- Computer architecture matters
- Machine learning brings you back to the physics

Density map of imploded shell



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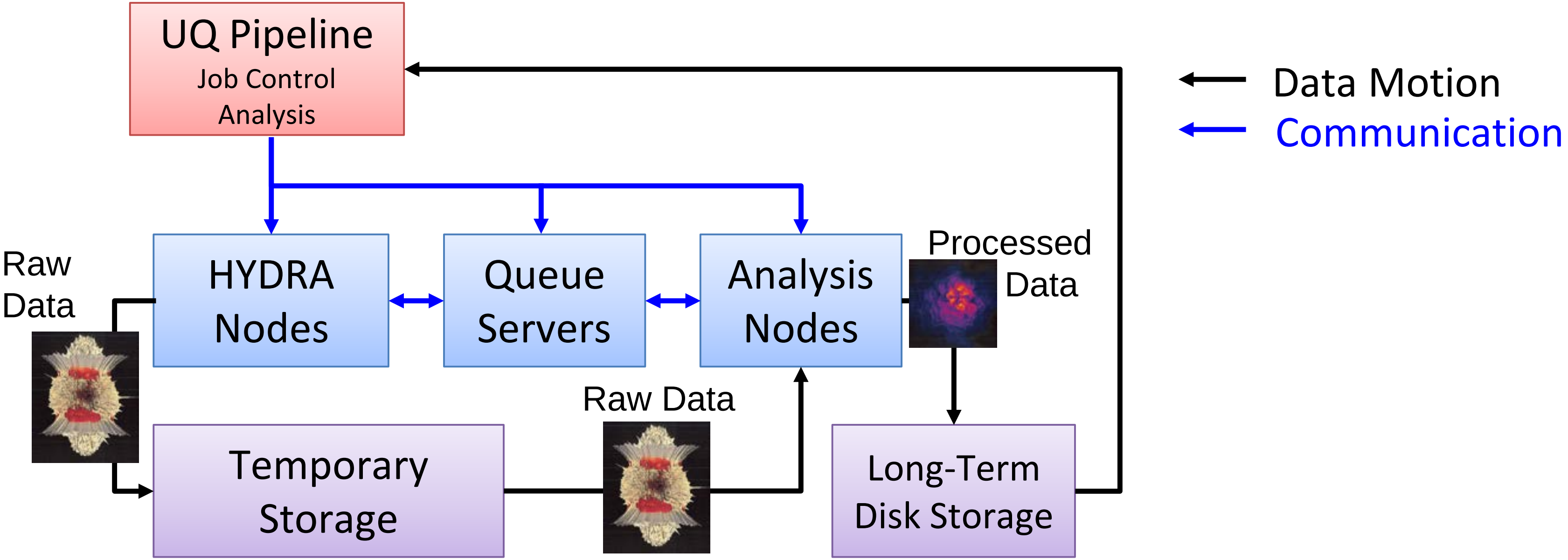
How did we do it?

1. Turned Trinity into a server farm with in-transit analysis



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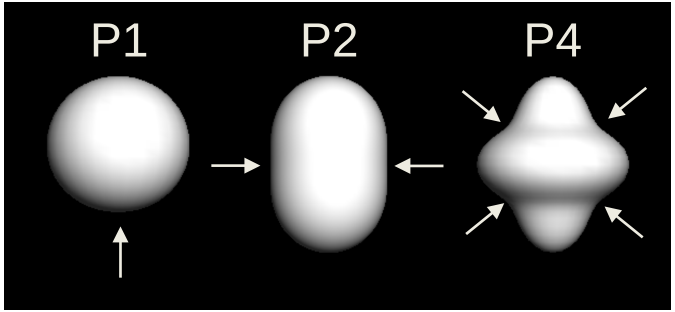
2. Ran a bunch of simulations of NIF implosions (30x more than any previous study)



- 9 ways to mess up a NIF implosion (parameters)
- Successfully completed 60k simulations
- 39 Million CPU Hours
- 5 PB Raw Data, 100 TB Processed & Zipped

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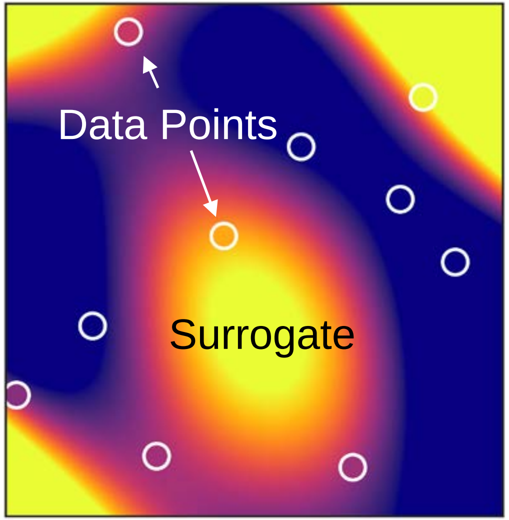
3. **Trained a ML model to fill in the gaps



** Summer Student Kelli Humbird (now LGSP)

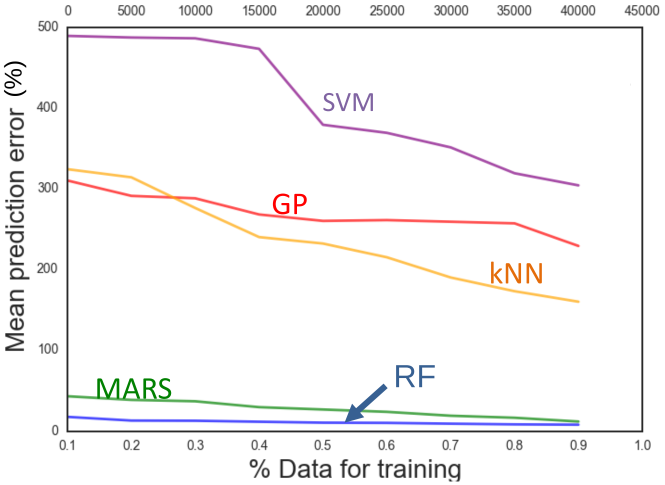
Random Forest surrogates, of all those tested, are the most accurate models for this dataset

- Tested multiple machine learning algorithms
  - Gaussian process, multivariate adaptive regression splines, nearest neighbor regression, support vector machines, random forests

- Dimensionality, volume of data, complexity of response surface (cliffs, peaks) make accurate interpolation challenging

- Random forest regressor most accurately models this ICF data

Mean error for yield models as a function of training data set size



Slide: K. Humbird

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Random forest yield model has 8% mean error when trained on 80% of the data

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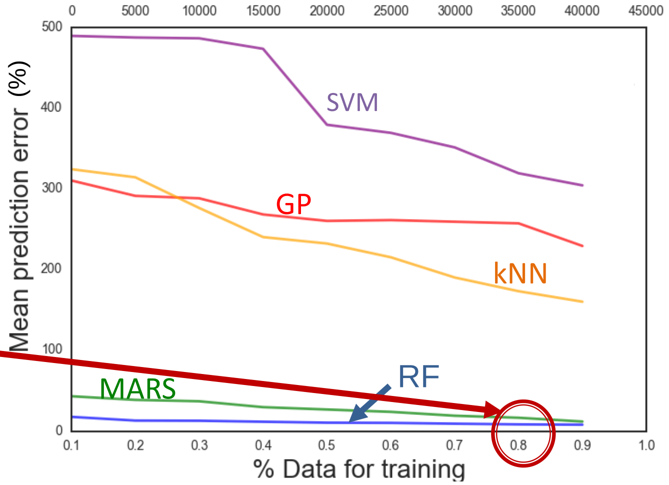

Slide: K. Humbird

See K. Humbird's Talk This Afternoon on Turning RFs into DNNs

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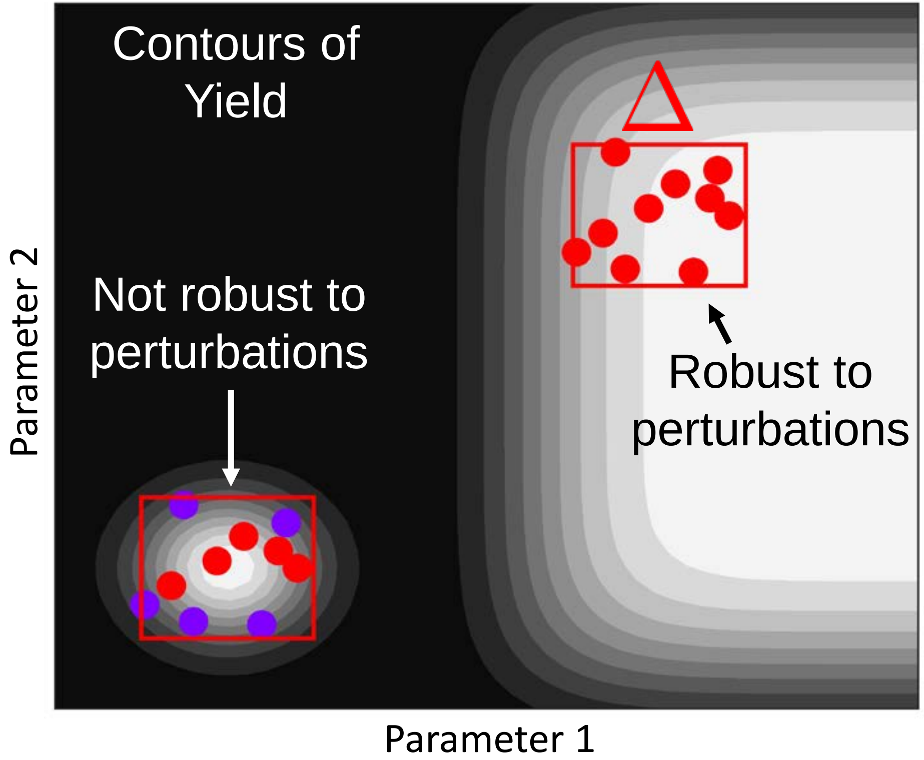

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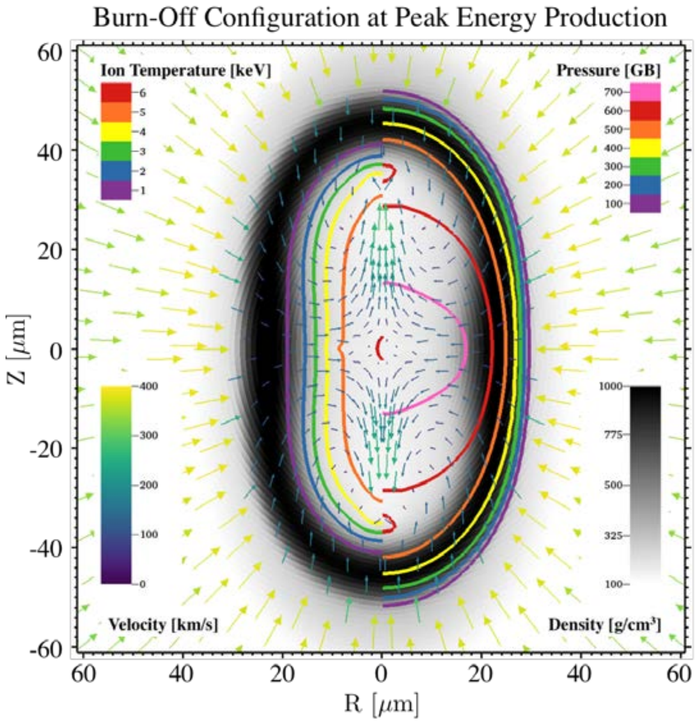
4. **Optimized the ML model for "robustness"
5. Ran new simulations at the predicted sweet spot & <u>dug into the physics</u>



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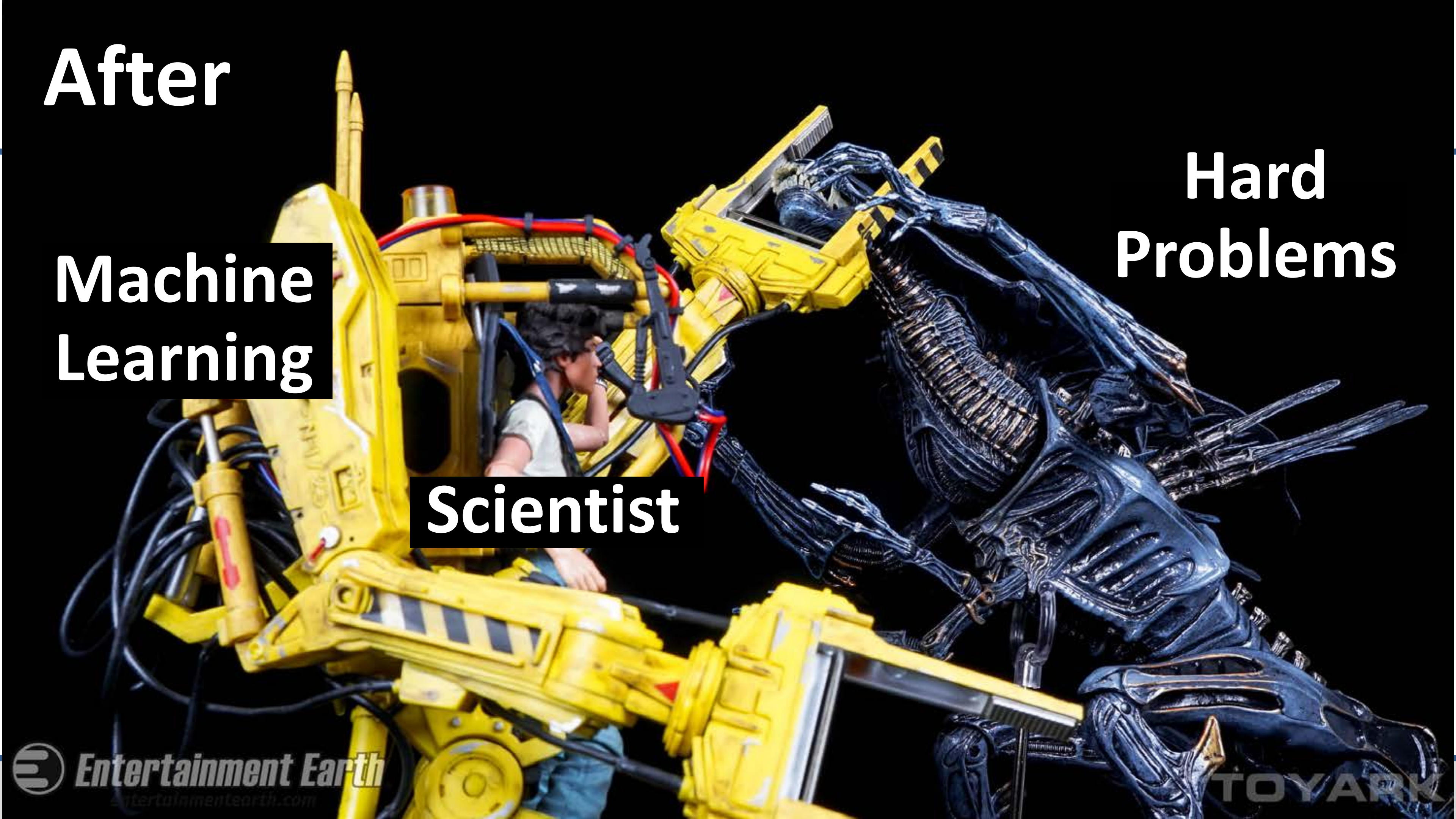
The Trinity Ovoid changed my view on how machine learning could help my do my job [HPC-enabled science].

Before


IM NOT LAZY...
Http://Facebook.com/TheRealNarutoMemes
IM HIGLY MOTIVATED AT
DOING NOTHING.
-Darui :3


After
Machine Learning
Scientist
Hard Problems
Entertainment Earth
entertainmentearth.com
TOYARK

Merlin

Machine Learning for HPC Workflows

Merlin

LBANN flux spindle celery conduit

sina UQPipeline DJINN ToNIC

Merlin

Brian Van Essen
tomorrow
afternoon

LBANN

flux spindle celery conduit

Kelli Humbird
this afternoon

DJINN

Jim Gaffney
this afternoon

ToNIC

sina UQPipeline

We’re aiming to make a “splash” for early Sierra access

- Generate **1 billion** semi-analytic ICF implosion simulations
  - Oversample a high-dimensional space
  - Train a deep learning model on a physics problem
  - Develop new physics insight
- Shareable data for the machine learning community
  - Beyond MNIST and ImageNET
  - Several billion images, plus scalars, time histories
- Challenging and meaningful problems unique to the Laboratory

1 Billion Sims!

IMAGENET

Lawrence Livermore National Laboratory

An exciting opportunity to establish Lab leadership in cognitive computing and data science

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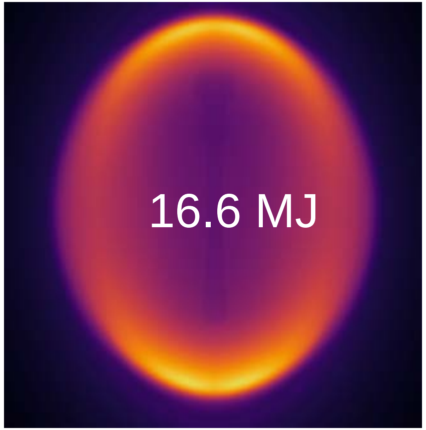

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Thank You!

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