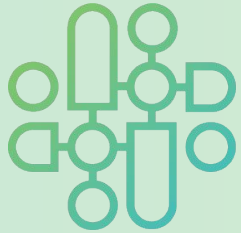

SC23
Denver, CO | i am hpc.

Why Do HPC?

What is a high-performance computing system and why would anyone use it?

Geoffrey Lentner, Rosen Center for Advanced Computing
John K. Holmen, Oak Ridge Leadership Computing Facility

What is a supercomputer?

- Built from many **servers**
- **Interconnected** over fast networks
- **Data** storage systems (similar)
- Typically running **UNIX**-like OS
- Managed by batch **scheduler**
- Running special **software**

HPE Cray EX2500 and Cray XD2000
https://www.hpe.com/us/en/compute/hpc.html

Personal computing is getting pretty *super*…

- Personal and lab **workstations** are orders of magnitude more **capable** and **affordable** than in previous decades
- *ARM*-based platforms with >30 **teraflops**
- Many **terabytes** of solid-state storage
- **Familiar**

Apple Mac Studio with M2 Ultra
https://www.apple.com/mac-studio/

When would you use a *supercomputer*?

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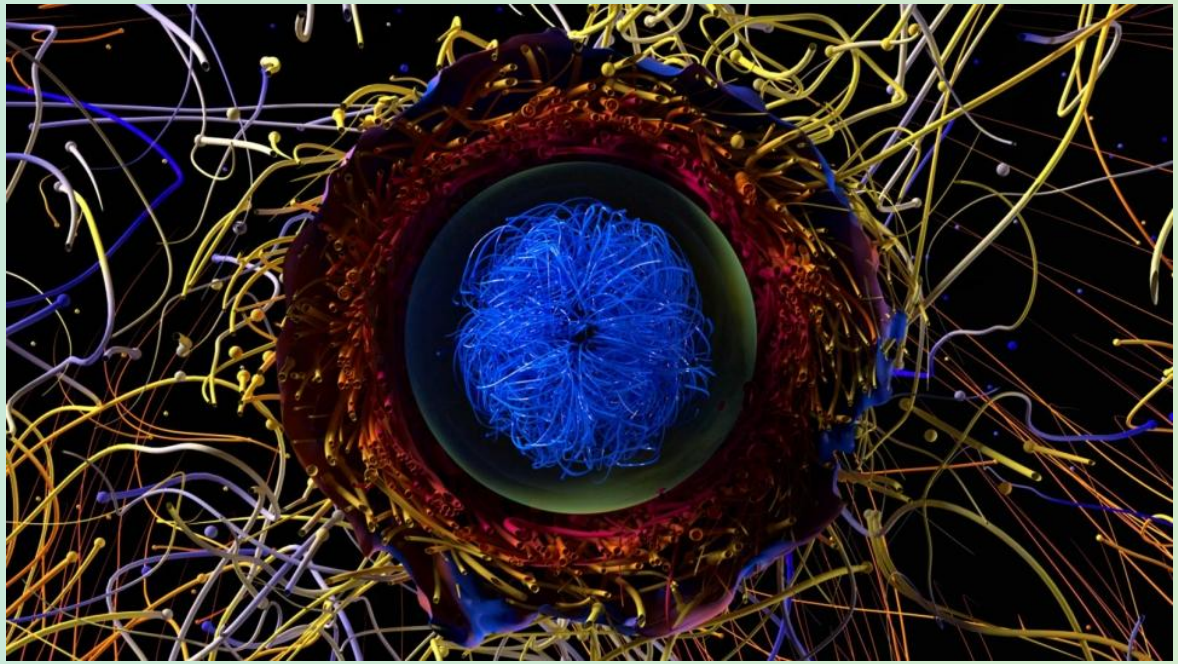
- Applications can be …
  - too ***slow***,
  - too ***many***,
  - too ***big***,
  - too ***complex***,
  - too ***expensive***,
  - too ***data intensive***, or even
  - too ***dangerous***



ALCF Visualization and Data Analytics Team;
Adam Burrows and the Princeton Supernova Theory Group, Princeton University
https://www.alcf.anl.gov/news/simulating-supernova-explosions-3d

Video: https://www.youtube.com/watch?v=0DSk1wPc_cE
SC22: Visualizing the Supernova Explosion of a 25-Solar-Mass Star and the Simultaneous Birth of ...

It's either *Capacity* or *Capability*

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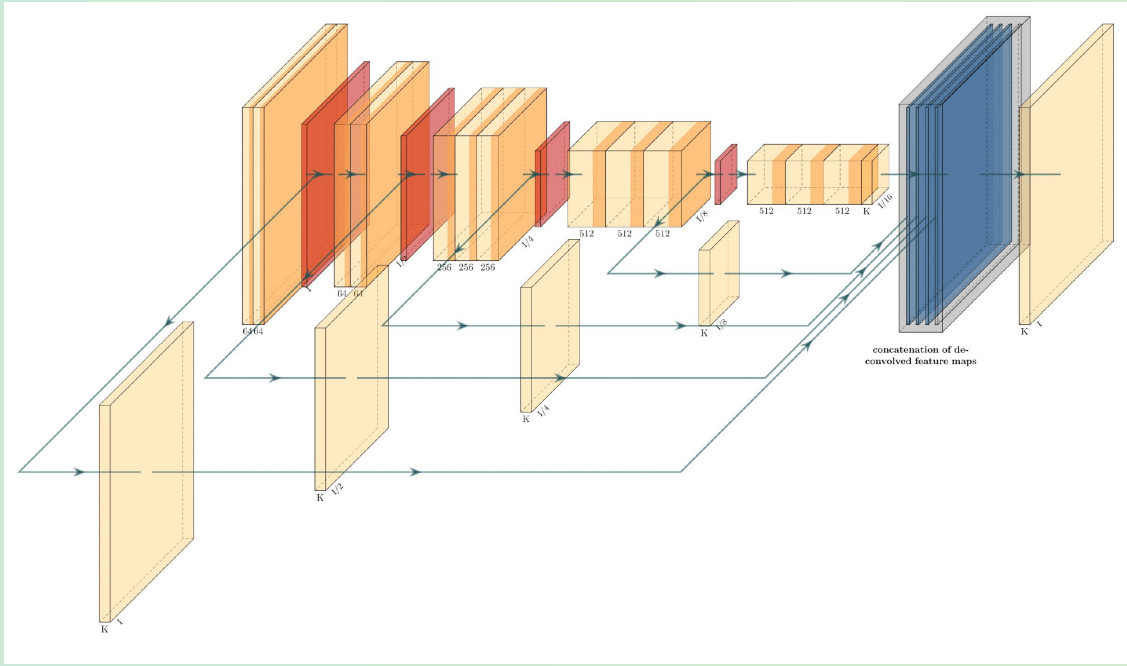
- Even things possible on a personal computer can require HPC because of limitations on *capacity*; e.g.,
  - **too many** tasks make the problem **too slow** to complete (months vs hours)
- For some applications, a personal computer is not *capable*; e.g.,
  - **too big** to simulate on a single machine, or
  - **too complex** to do on normal hardware, or
  - **too expensive** or **too dangerous** to allow study in the real-world

Too *many* and too *slow* …

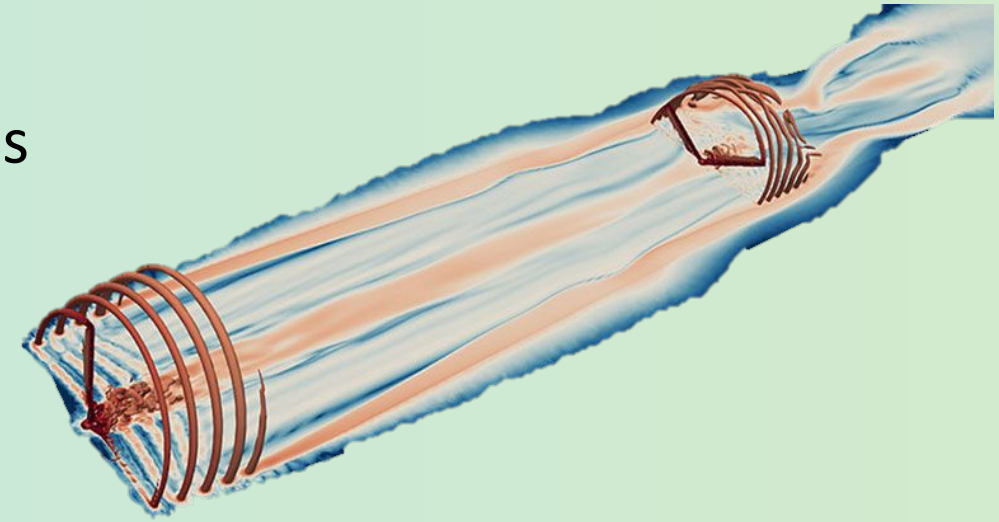
- **Deep learning** is possible, but
  - train faster on specialized hardware, and
  - exploring many, many models can take months on a single machine
- **Data processing** is possible, but
  - there might be too much data for your local hard drive, or
  - processing in *serial* can be too slow



FCN-32 (plotted using *PlotNeuralNet*)
https://github.com/HarisIqbal88/PlotNeuralNet

Too *big* and too *complex* …

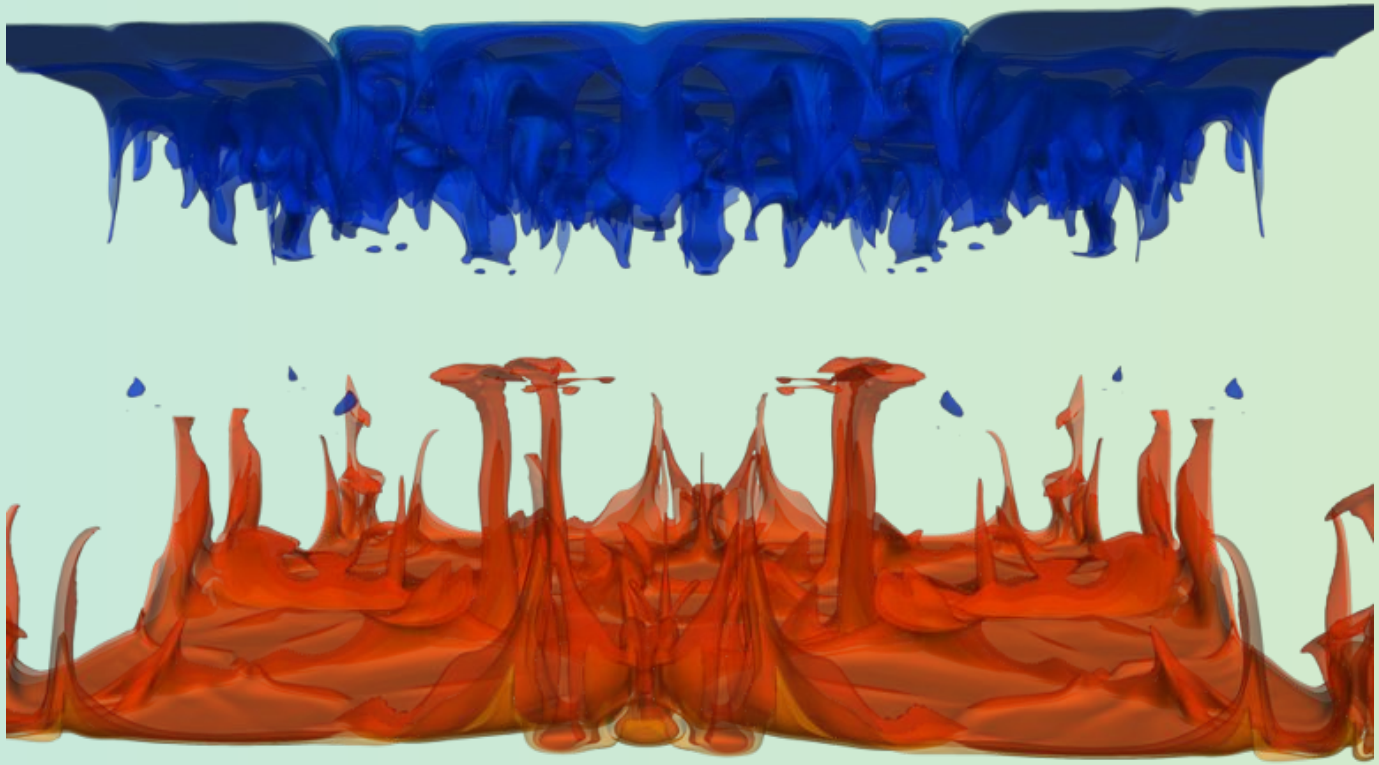
- **Scheduling** for airlines routing thousands of flights and millions of passengers;
  - too complex to complete in a timely fashion with so many variables and permutations
- **Trajectory planning** for space-flight missions
  - too complex, involving incredible fidelity over long time spans,
- **Model simulations** for turbine efficiency
  - too big to simulate on one machine



Wind Turbine Modeling and Validation, National Renewable Energy Lab (NREL)
https://www.nrel.gov/wind/modeling-validation.html

Too *expensive* and too *dangerous* …

- **Weapons research**
  - Cannot detonate weapons
- **Nuclear reactor safety**
  - Cannot intentionally melt down a nuclear reactor



Lentner 2023, in prep

What is a Leadership Computing Facility (LCF)?

- LCF centers partner with users to enable science and engineering breakthroughs
- **Mission:** Deploy and operate the computational and data resources required for such breakthroughs
- LCF centers provide resources to investigate otherwise inaccessible systems at every scale
  - Galaxy Formation and Supernovae to Automobiles and Nanomaterials

https://www.flickr.com/photos/olcf/52117623798

Oak Ridge Leadership Computing Facility (OLCF)

- One of two Department of Energy LCF's
- Based in Oak Ridge, TN at the Oak Ridge National Laboratory (ORNL)
- Department of Energy-funded research
  - Neutron Science, High-Performance Computing, Advanced Materials, Biology and Environmental Science, Nuclear Science and Engineering, Isotopes, and National Security
- Largest, most modern center for unclassified computing in the US

https://www.ornl.gov/sites/default/files/styles/basic_page_hero/public/2008-P01679.jpg

ORNL has had a Top 10 supercomputer in every year since the OLCF was founded in 2005

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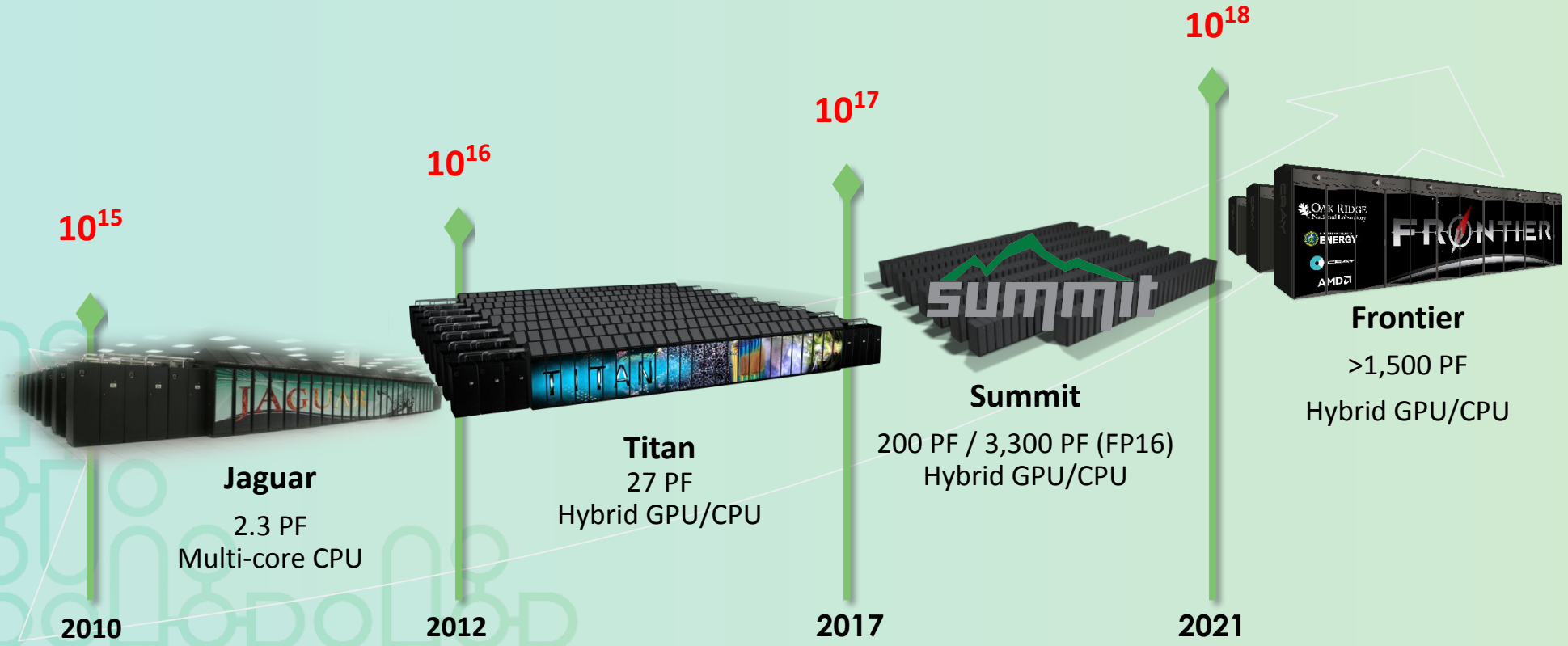


#1 World's Fastest Computer in 2009

#1 World's Fastest Computer in 2012

#1 World's Fastest Computer in 2018

Nation's 1st Exascale System

Frontier Fun Facts

- 1 Exaflop => 10^{18} Calculations per Second
  - Frontier can do in 1 second what would take over 4 years if everyone on Earth did 1 calculation per second
- Theoretical peak of 2 Exaflop
  - Compute similar to 194,544 PS5s
- Achieved peak of 1.194 Exaflop
  - First exascale system on Top500
- System consists of 9,408 nodes
  - 9,408 CPUs and 75,264 logical GPUs

https://www.flickr.com/photos/olcf/52117588486/

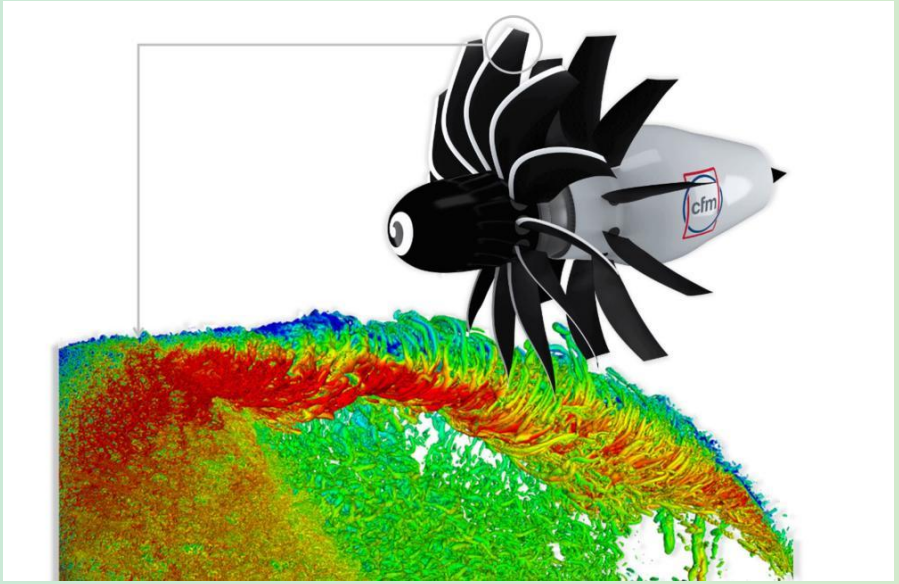
Frontier Fun Facts

- 74 cabinets weighing 8,000 pounds each
  - Total weight similar to a Boeing 747
- 90 miles of cables
  - Denver, CO to Wyoming Border
- 6,000 gallons of water moved per minute
  - Pumps can fill an Olympic pool in 30 minutes
- 700 PB of storage
  - 25 Mt. Everests of DVDs

https://www.flickr.com/photos/olcf/52117839159/

Example Use Case

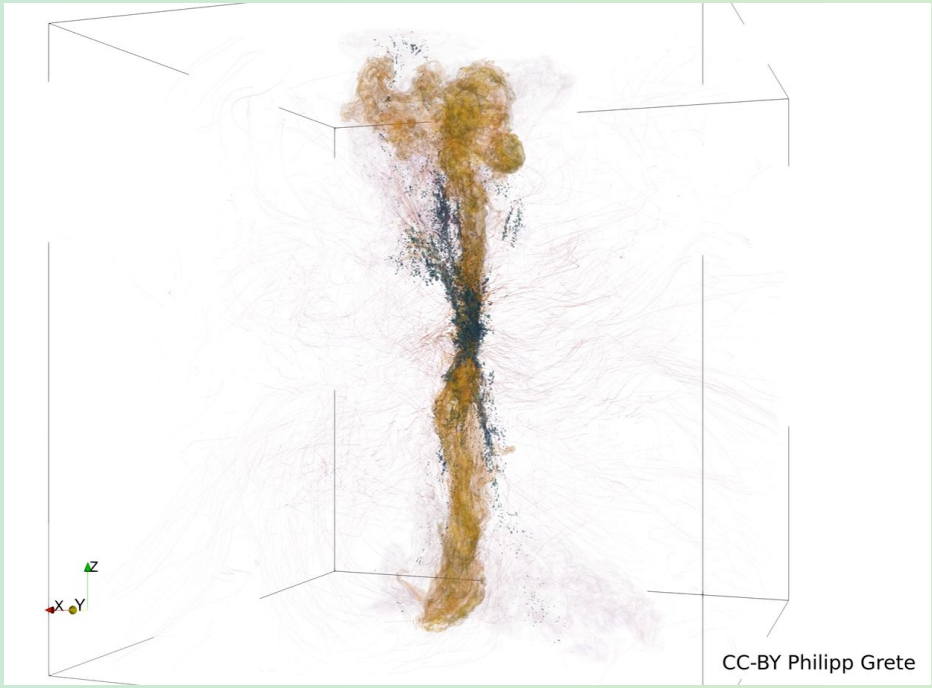
- GE Aerospace is designing next-gen commercial aircraft engines
- Frontier enables better evaluation of engine technologies at flight scale
- Software designed to model engine performance and noise levels
- Resulting runs simulated air movement for a full-scale open fan engine design with incredible detail



Credit: CFM, GE Research
https://www.ornl.gov/sites/default/files/styles/main_image_style/public/2023-08/GEAerospaceEngine.jpg

Example Use Case

- An INCITE team is simulating a more detailed universe
- Frontier enables higher levels of resolution
- Software designed to model turbulence and feedback from active galactic nuclei jets in galaxy groups and clusters
- Resulting runs simulated the jet and surrounding diffuse plasma with incredible detail



Questions?

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