Ascent: Flyweight In Situ Visualization and Analysis for HPC Simulations

LLNL RADIUSS AWS Tutorial Series

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Nicole Marsaglia (LLNL)

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Acknowledgements

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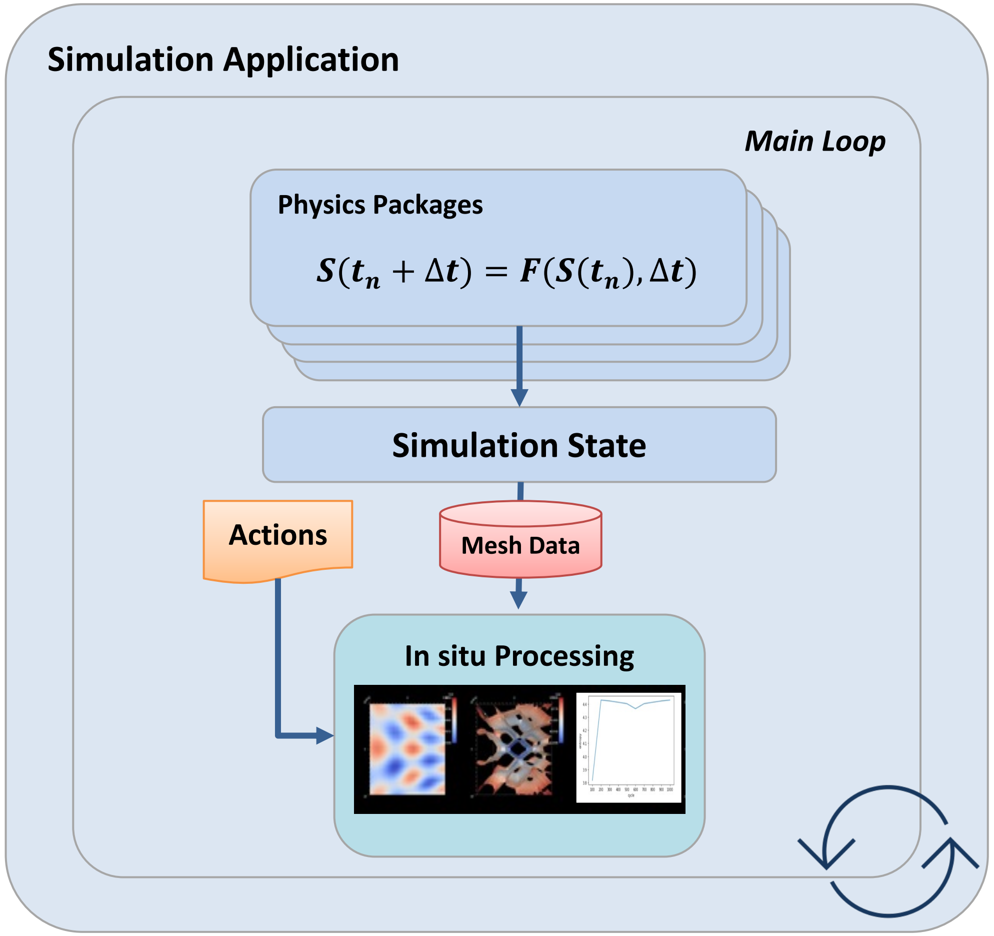
What Is In Situ Processing?

- Defined:
  - Process data while it is generated
  - Couple visualization and analysis routines with the simulation code (avoiding file system I/O)
- Pros:
  - No or greatly reduced I/O vs post-hoc processing
  - Can access all the data
  - Computational power readily available
- Cons:
  - More difficult when lacking a priori knowledge of what to visualize/analyze
  - Increasing complexity
  - Constraints (memory, network)



(Slide Acknowledgement: Hank Childs)

Important links and contact info:

Ascent Resources:

- Github: https://github.com/alpine-dav/ascent
- Docs: http://ascent-dav.org/
- Tutorial Landing Page: https://www.ascent-dav.org/tutorial/

Contact Info:

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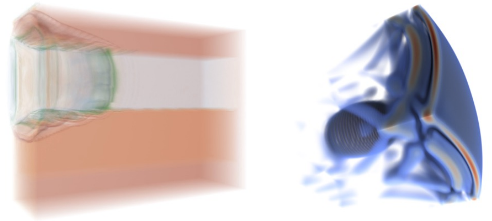
Nicole Marsaglia: marsaglia1@llnl.gov

Ascent is an easy-to-use flyweight in situ visualization and analysis library for HPC simulations

- **Easy to use in-memory visualization and analysis**
  - Use cases: ***Making Pictures, Transforming Data,*** and ***Capturing Data***
  - Young effort, yet already supports most common visualization operations
  - Provides a simple infrastructure to integrate custom analysis
  - Provides C++, C, Python, and Fortran APIs
- **Uses a flyweight design targeted at next-generation HPC platforms**
  - Efficient distributed-memory (MPI) and many-core (CUDA, HIP, OpenMP) execution
    - Demonstrated scaling: In situ filtering and ray tracing across ***16,384 GPUs*** on LLNL's Sierra Cluster
  - Has lower memory requirements than current tools
  - Requires less dependencies than current tools (ex: no OpenGL)
    - Builds with Spack https://spack.io/

Ascent



Visualizations created using Ascent

python™ HDF CINEMA

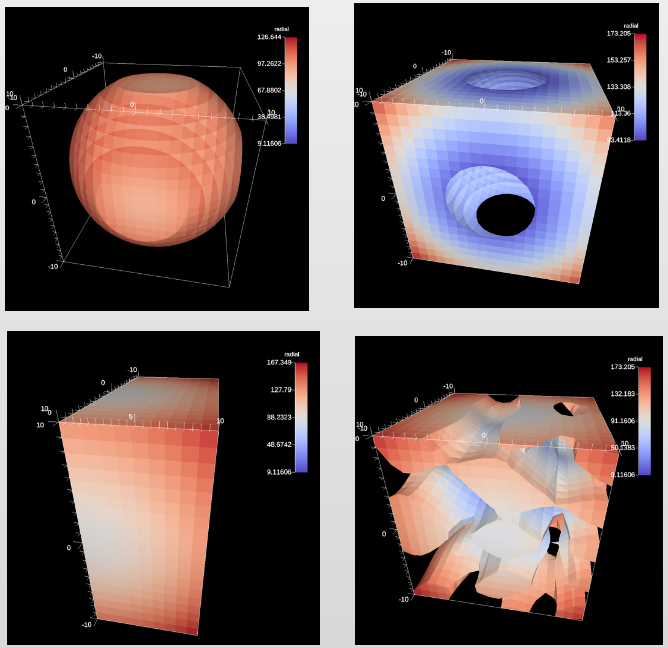
Extracts supported by Ascent

http://ascent-dav.org

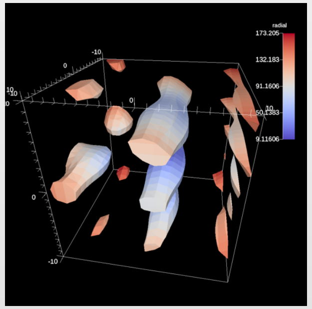
https://github.com/Alpine-DAV/ascent

Website and GitHub Repo

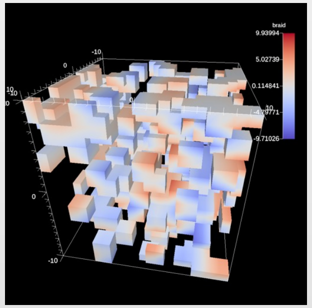
Ascent supports common visualization use cases



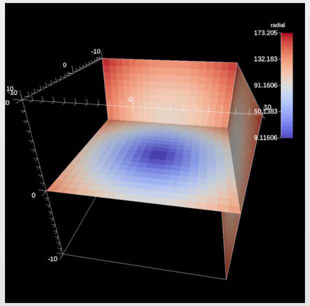
Clips



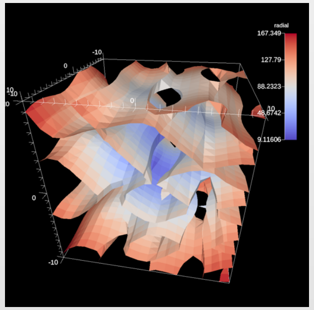
Iso-Volume



Threshold



Slice

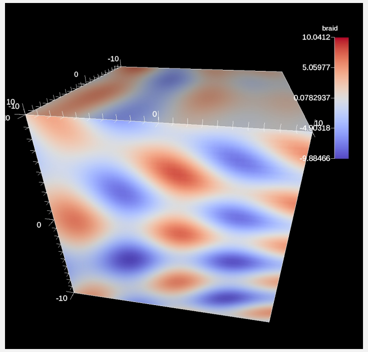


Contour

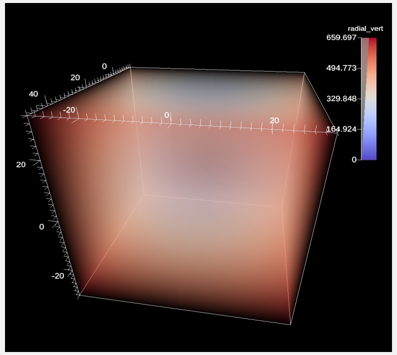
[powered by]

VTK-m RAJA mfem Devil Ray

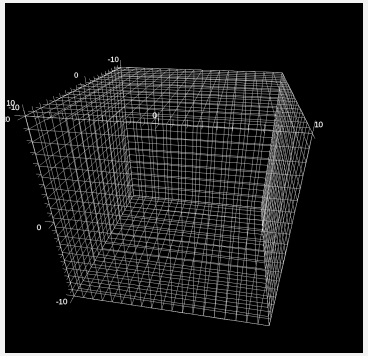
Rendering



Pseudocolor



Volume

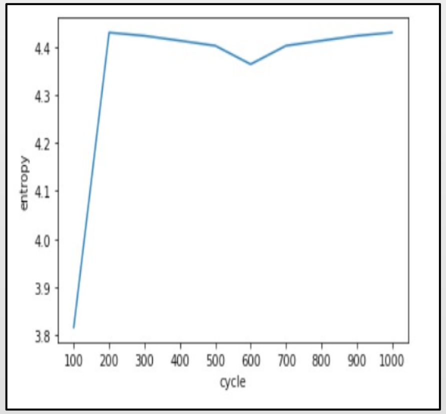


Mesh

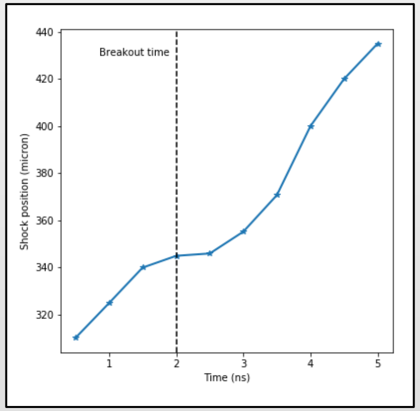
Ascent supports common analysis use cases

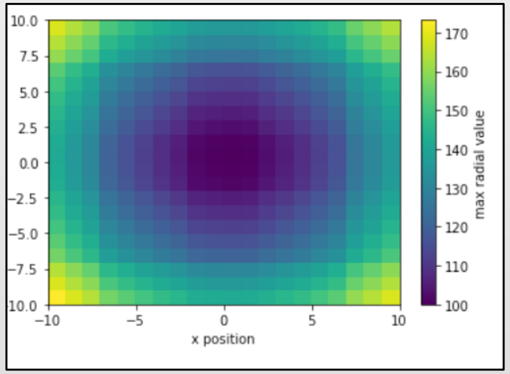
```
expression: |
  du = gradient(field('velocity','u'))
  dv = gradient(field('velocity','v'))
  dw = gradient(field('velocity','w'))
  w_x = dw.y - dv.z
  w_y = dw.z - dv.x
  w_z = dw.x - dv.y
  vector(w_x,w_y,w_z)
name: vorticity
```

Derived Fields



Time Histories



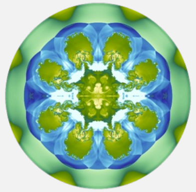


Lineouts and Spatial Binning

```
condition:
  entropy - history(entropy,
            relative_index = 1) > 0.5
```

Triggers

Extracts



Scalar Images

HDF5 Files

Cinema Databases

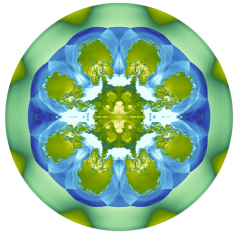
python powered

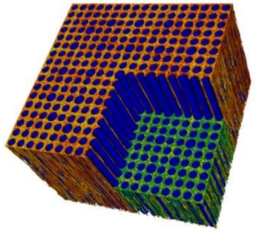
jupyter

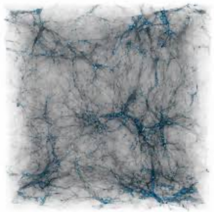
We are working to integrate and deploy Ascent with HPC simulation codes (ECP and beyond)

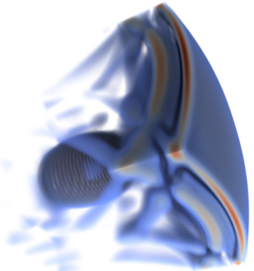
CEED
EXASCALE DISCRETIZATIONS

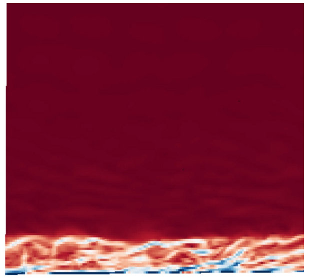
AMReX


MARBL


NekRS


Nyx

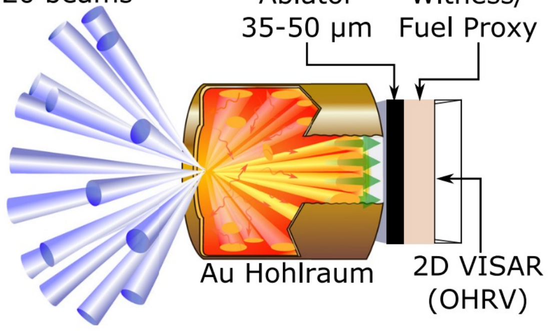

WarpX


AMRWind

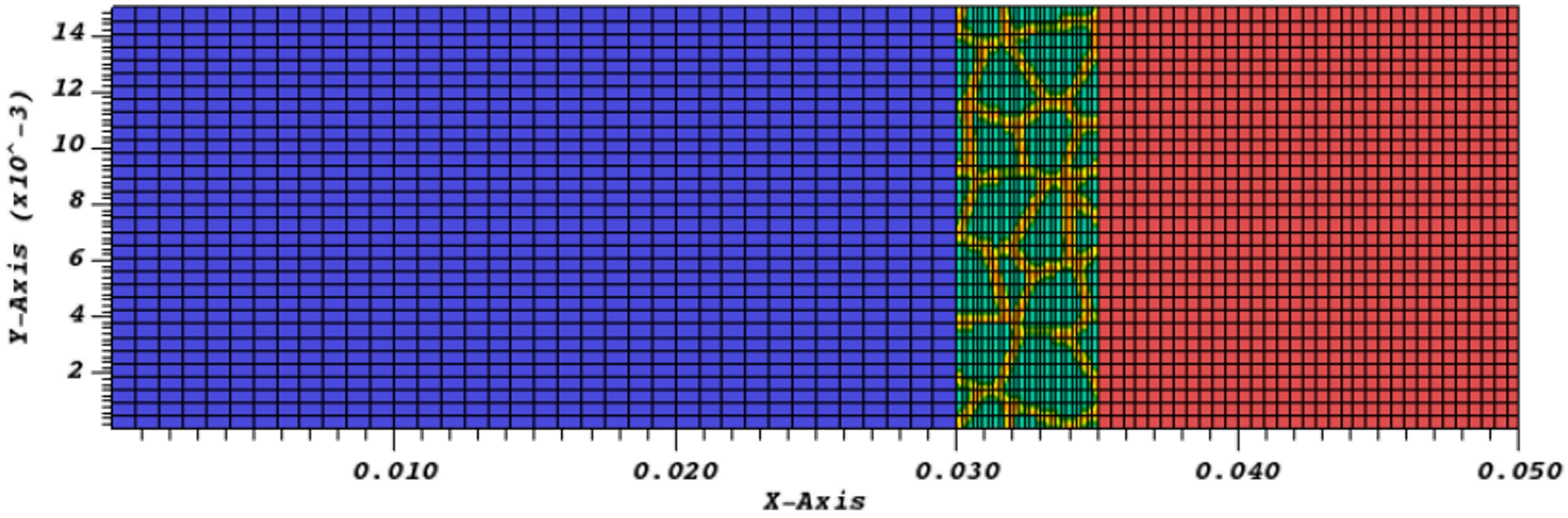

Pele

Ascent

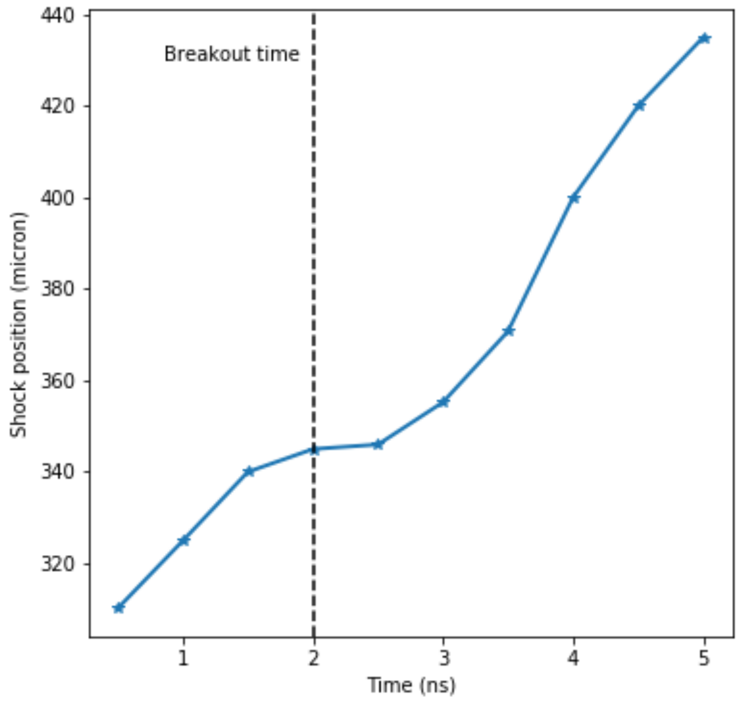
Science Enabling Results: Shock Front Tracking (VISAR)



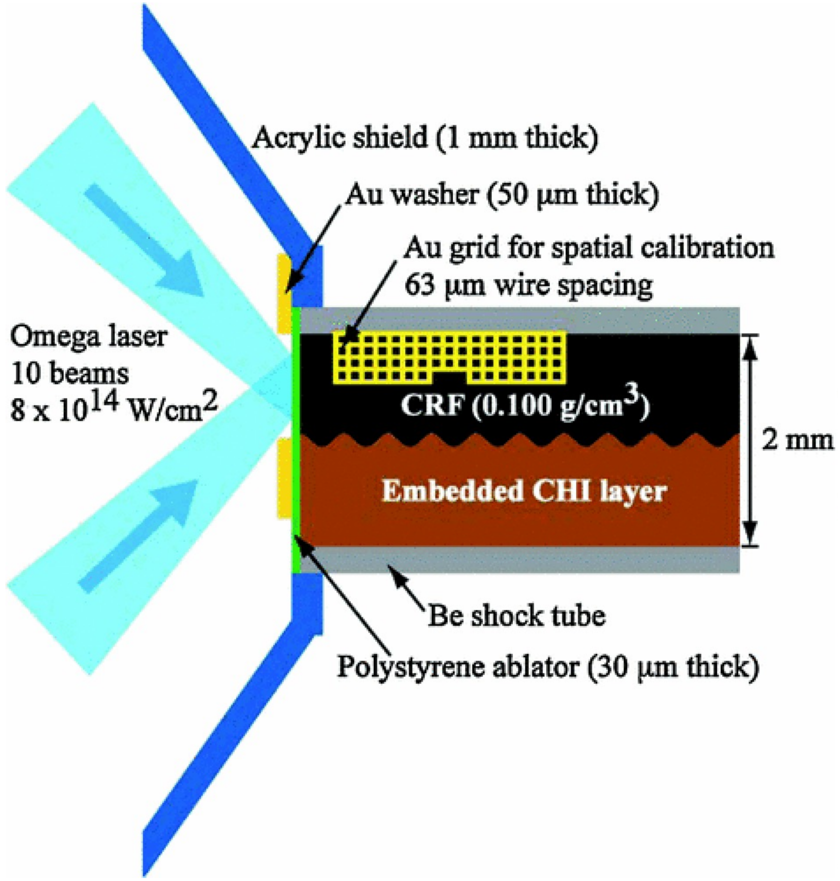
Velocity interferometer system for any reflector (VISAR)



Shock position tracked in Ascent

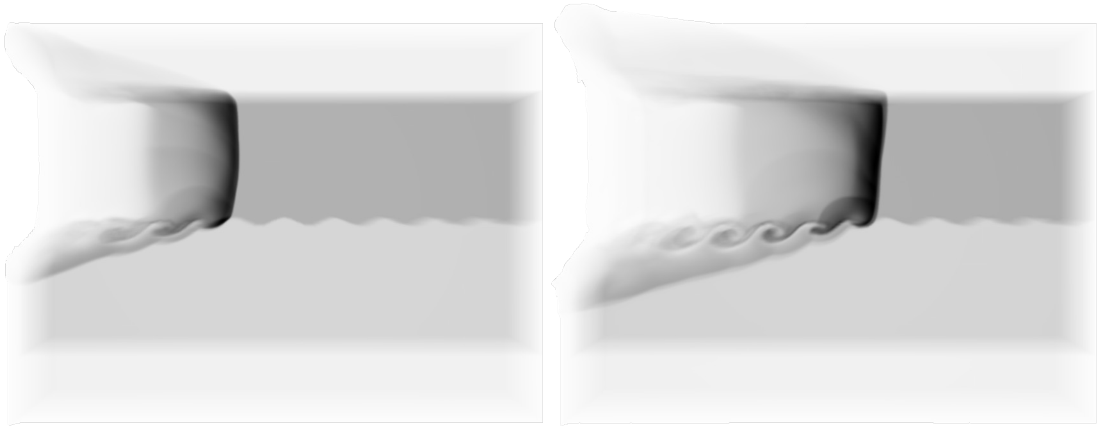


Science Enabling Results: Simulation Validation

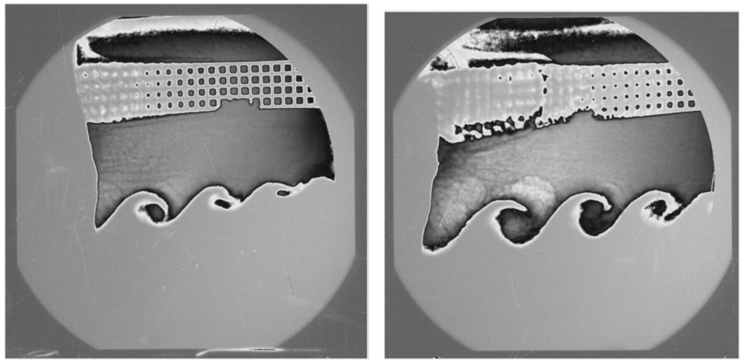


Radiographs

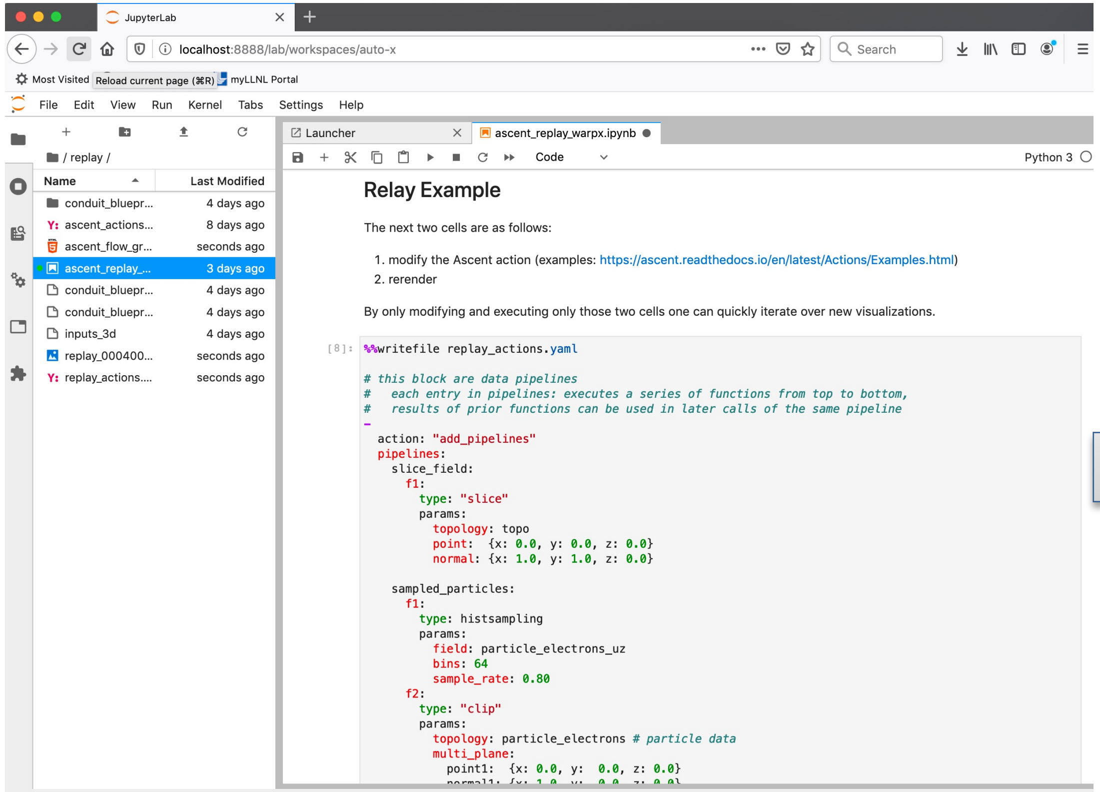
Simulated



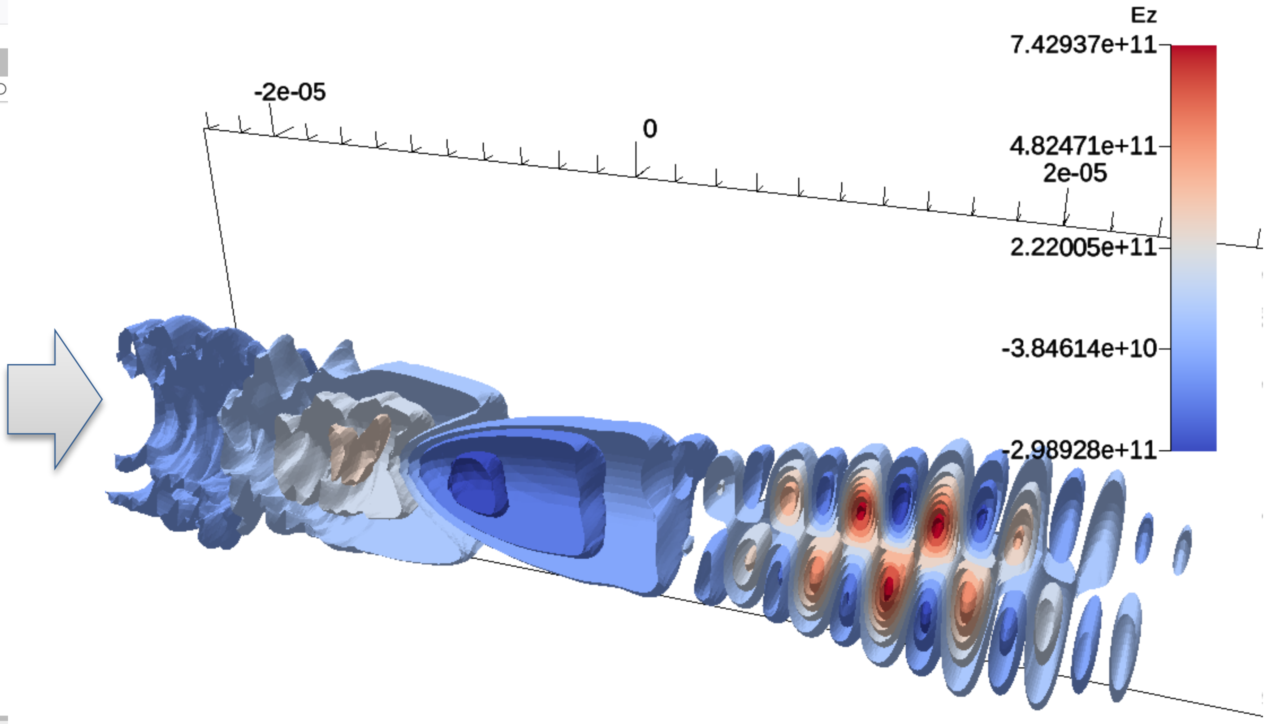
Experimental



Science Enabling Results: WarpX Workflow Tools (Jupyter Lab)



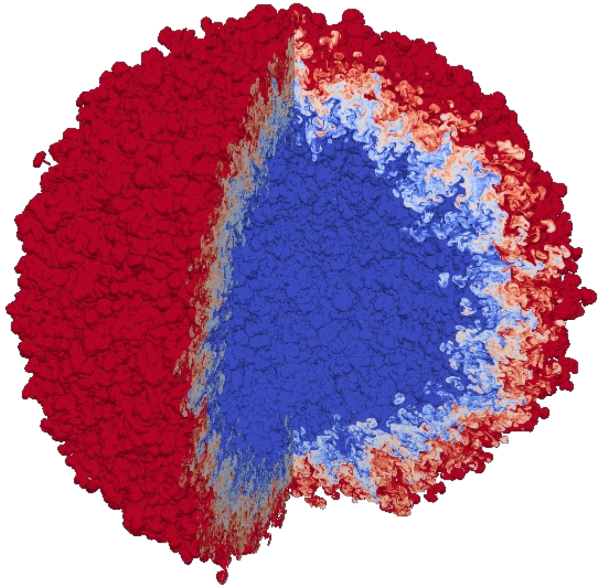
Jupyter Lab Interface



Resulting Image

Science Enabling Results: Rendering At Scale (2018)

- The ***97.8 billion*** element simulation ran across ***16,384 GPUs*** on ***4,096 Nodes***
- The simulation application used **CUDA** via **RAJA** to run on the GPUs
- Time-varying evolution of the mixing was visualized in-situ using **Ascent**, also leveraging 16,384 GPUs
- Ascent leveraged **VTK-m** to run visualization algorithms on the GPUs



Visualization of an idealized Inertial Confinement Fusion (ICF) simulation of Rayleigh-Taylor instability with two fluids mixing in a spherical geometry.

Today we will teach you about Ascent's API and capabilities

You will learn:

- How to use Conduit, the foundation of Ascent's API

- How to get your simulation data into Ascent

- How to tell Ascent what pictures to render and what analysis to execute

Ascent tutorial examples are outlined in our documentation and included ready to run in Ascent installs

Ascent

latest

Search docs

- Quick Start
- Ascent User Documentation
- Developer Documentation
- ⊟ Tutorial
  - Tutorial Setup
  - Introduction to Ascent
  - CloverLeaf3D Ascent Demos
- Releases
- Publications and Presentations

Docs » Tutorial

Edit on GitHub

Tutorial

This tutorial introduces how to use Ascent, including basics about:

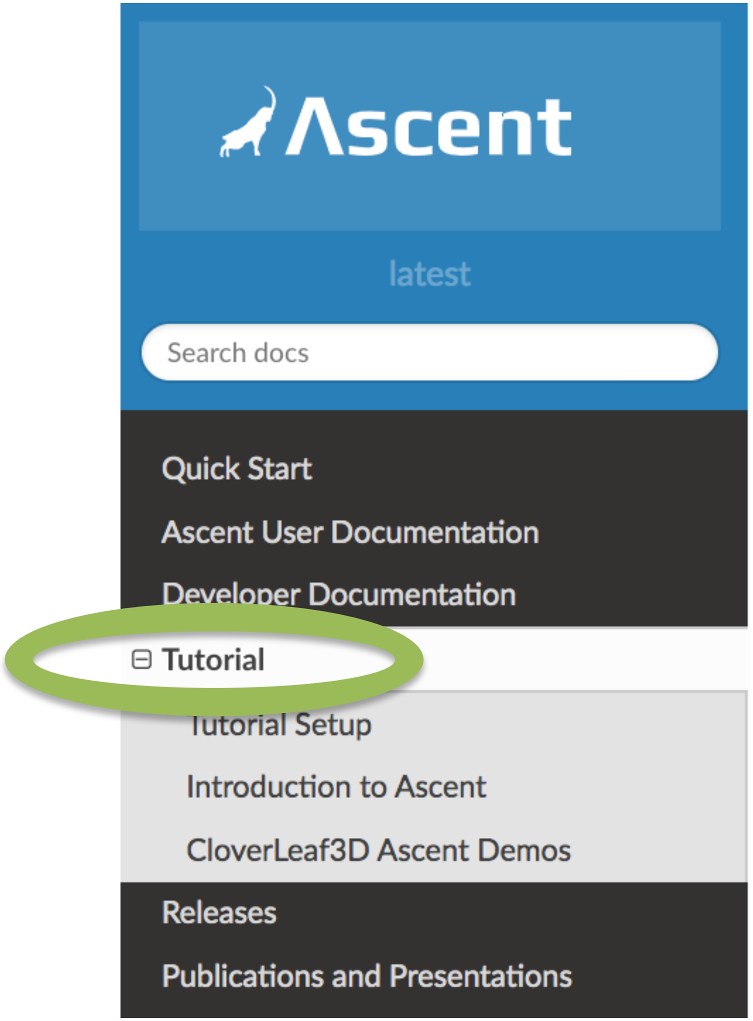
- Formating mesh data for Ascent
- Using Conduit and Ascent's Conduit-based API
- Using and combining Ascent's core building blocks: Scenes, Pipelines, Extracts, Queries, and Triggers
- Using Ascent with the Cloverleaf3D example integration

Ascent installs include standalone C++, Python, and Python-based Jupyter notebook examples for this tutorial. You can find the tutorial source code and notebooks in your Ascent install directory under `examples/ascent/tutorial/ascent_intro/` and the Cloverleaf3D demo files under `examples/ascent/tutorial/cloverleaf_demos/`.

http://ascent-dav.org

Ascent tutorial examples are outlined in our documentation and included ready to run in Ascent installs

- http://ascent-dav.org
- Click on “Tutorial”



Ascent’s interface provides five top-level functions

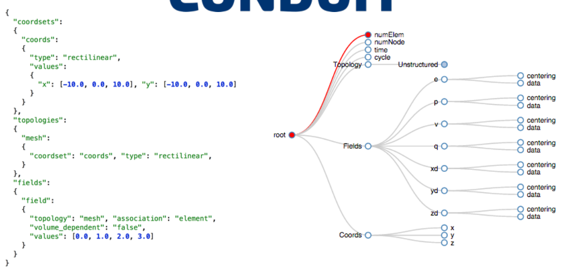
- **open() / close()**
  - Initialize and finalize an Ascent instance
- **publish()**
  - Pass your simulation data to Ascent
- **execute()**
  - Tell Ascent what to do
- **info()**
  - Ask for details about Ascent’s last operation

```
//
// Run Ascent
//

Ascent ascent;
ascent.open();

ascent.publish(data);
ascent.execute(actions);
ascent.info(details);

ascent.close();
```

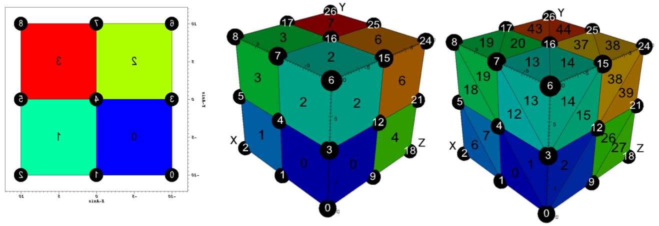
The *publish(), execute(),* and *info()* methods take Conduit trees as an argument.
What is a Conduit tree?

Conduit provides intuitive APIs for in-memory data description and exchange

- **Provides an intuitive API for in-memory data description**
  - Enables *human-friendly* hierarchical data organization
  - Can describe in-memory arrays without copying
  - Provides C++, C, Python, and Fortran APIs
- **Provides common conventions for exchanging complex data**
  - Shared conventions for passing complex data (e.g. *Simulation Meshes*) enable modular interfaces across software libraries and simulation applications
- **Provides easy to use I/O interfaces for moving and storing data**
  - Enables use cases like binary checkpoint restart
  - Supports moving complex data with MPI (serialization)



Hierarchical in-memory data description



Conventions for sharing in-memory mesh data

http://software.llnl.gov/conduit
http://github.com/llnl/conduit

Website and GitHub Repo

Ascent uses Conduit to provide a flexible and extendable API

- Conduit underpins Ascent's support for C++, C, Python, and Fortran interfaces
- Conduit also enables using YAML to specify Ascent actions
- Conduit's zero-copy features help couple existing simulation data structures
- Conduit Blueprint provides a standard for how to present simulation meshes

Learning Ascent equates to learning how to construct and pass Conduit trees that encode your data and your expectations.

To start, let’s look at the Ascent “First Light” Example in C++

- https://ascent.readthedocs.io/en/latest/Tutorial_Intro_First_Light.html

```
#include <iostream>

#include "ascent.hpp"
#include "conduit_blueprint.hpp"

using namespace ascent;
using namespace conduit;

int main(int argc, char **argv)
{
    // echo info about how ascent was configured
    std::cout << ascent::about() << std::endl;

    // create conduit node with an example mesh using
    // conduit blueprint's braid function
    // ref: https://llnl-conduit.readthedocs.io/en/latest/blueprint_mesh.html#braid

    // things to explore:
    //  changing the mesh resolution

    Node mesh;
    conduit::blueprint::mesh::examples::braid("hexs",
                                              50,
                                              50,
                                              50,
                                              mesh);
```

Instrument your “main” loop or similar function with access to evolving simulation state

This code generates an example mesh

To start, let’s look at the Ascent “First Light” Example in C++

- https://ascent.readthedocs.io/en/latest/Tutorial_Intro_First_Light.html

```
// create an Ascent instance
Ascent a;

// open ascent
a.open();
```

Create an Ascent instance and set it up

```
// publish mesh data to ascent
a.publish(mesh);
```

Now Ascent has access to our mesh data

To start, let's look at the Ascent "First Light" Example in C++

- https://ascent.readthedocs.io/en/latest/Tutorial_Intro_First_Light.html

```
//
// Ascent's interface accepts "actions"
// that to tell Ascent what to execute
//
Node actions;
Node &add_act = actions.append();
add_act["action"] = "add_scenes";

// Create an action that tells Ascent to:
// add a scene (s1) with one plot (p1)
// that will render a pseudocolor of
// the mesh field `braid`
Node & scenes = add_act["scenes"];

// things to explore:
//  changing plot type (mesh)
//  changing field name (for this dataset: radial)
scenes["s1/plots/p1/type"] = "pseudocolor";
scenes["s1/plots/p1/field"] = "braid";
// set the output file name (ascent will add ".png")
scenes["s1/image_name"] = "out_first_light_render_3d";
```

Create a tree that describes the actions we want Ascent to do

```
-
  action: "add_scenes"
  scenes:
    s1:
      plots:
        p1:
          type: "pseudocolor"
          field: "braid"
      image_name: "out_first_light_render_3d"
```

```
// view our full actions tree
std::cout << actions.to_yaml() << std::endl;
```

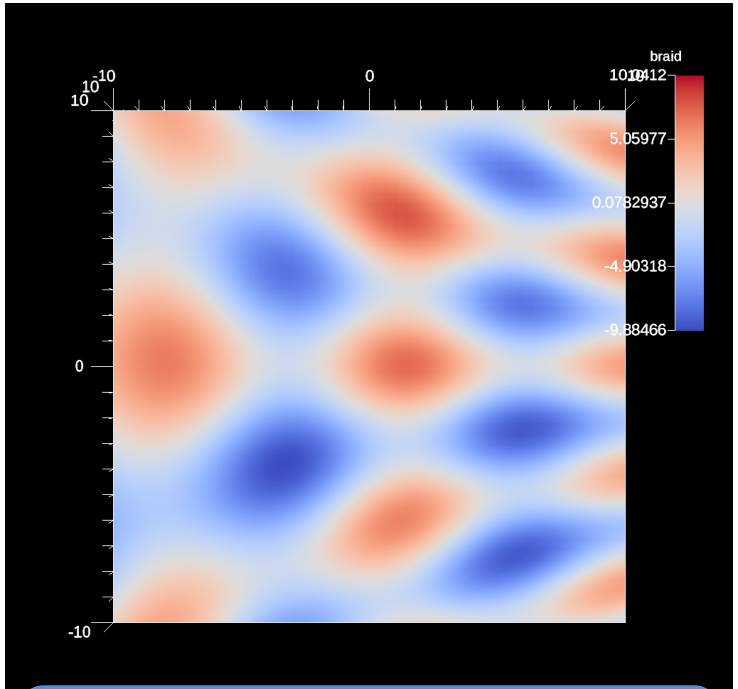
Equivalent YAML Description

To start, let's look at the Ascent "First Light" Example in C++

- https://ascent.readthedocs.io/en/latest/Tutorial_Intro_First_Light.html

```
// execute the actions
a.execute(actions);
```

Tell Ascent to execute these actions



Rendered Result!

Ascent's interface provides five composable building blocks

Scenes
(Render Pictures)

Pipelines
(Transform Data)

Extracts
(Capture Data)

Queries
(Ask Questions)

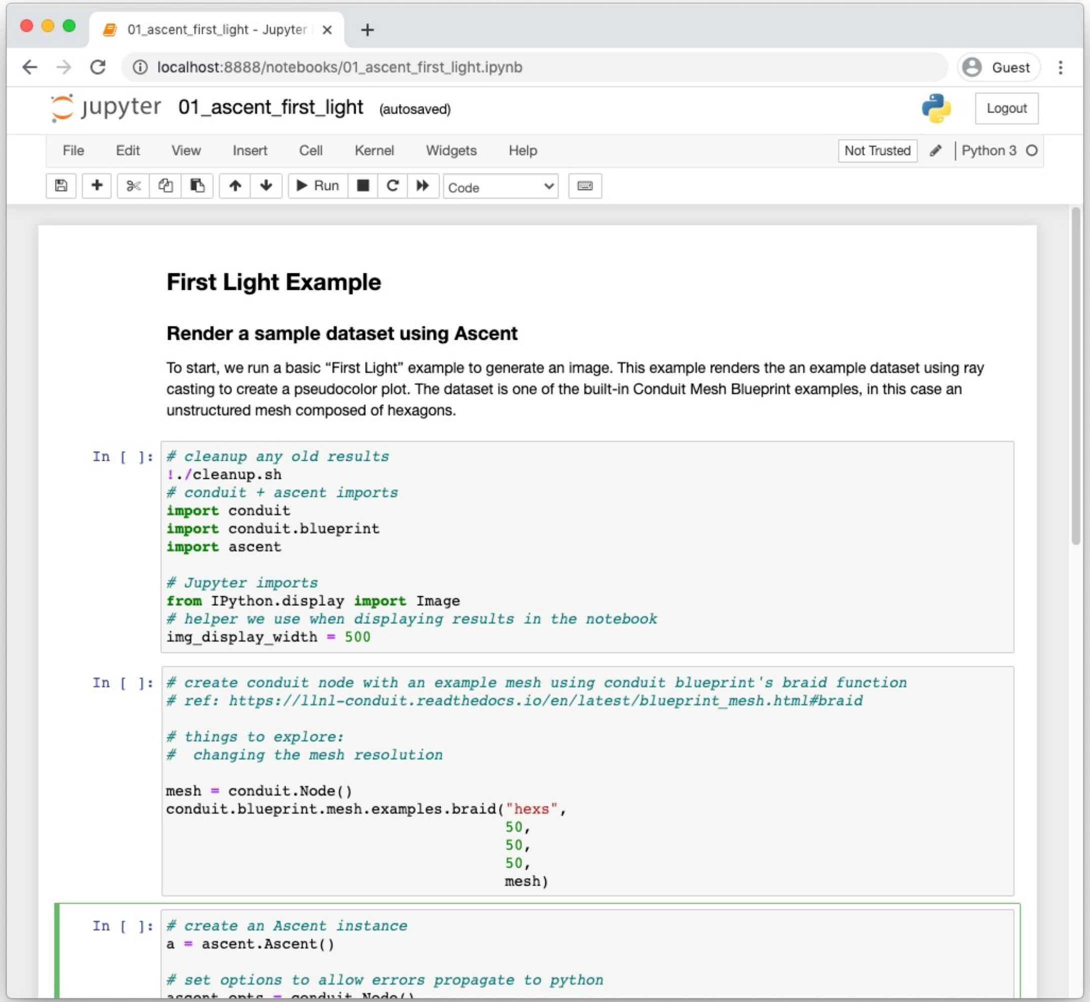
Triggers
(Adapt Actions)

The tutorial provides examples for all of these.

For the reminder of the tutorial, we will run the Ascent Tutorial examples using Jupyter Notebooks

NOTE:

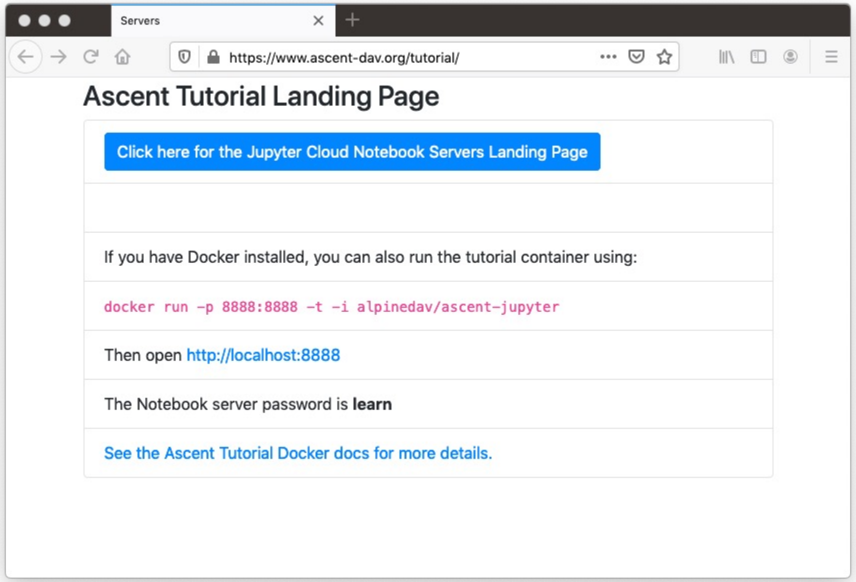
- VPNs or firewalls may block access to general AWS IP addresses and ports
- You may need to disconnect from VPN or request a firewall exemption
- LLNL attendees, you can use the EOR process: https://cspservices.llnl.gov/eor/



You can run our tutorial examples using cloud hosted Jupyter Lab servers

Start here:

https://www.ascent-dav.org/tutorial/



Thanks!

Ascent Resources:

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- Docs: http://ascent-dav.org/
- Tutorial Landing Page: https://www.ascent-dav.org/tutorial/

Contact Info:

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Nicole Marsaglia: marsaglia1@llnl.gov

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Lawrence Livermore National Security, LLC

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