NVIDIA IndeX
Introduction

19 July 2024
Version 2.3

NVIDIA IndeX – Introduction

Copyright Information

Document build number rev376353

Contents

1 Advancing science

The NVIDIA IndeX® framework sets a new standard for scientific visualization. Building on the latest advances in accelerated compute, NVIDIA IndeX can render volume data of virtually any size. Visualizations are precise and accurate and can be explored and analyzed interactively, in real time.
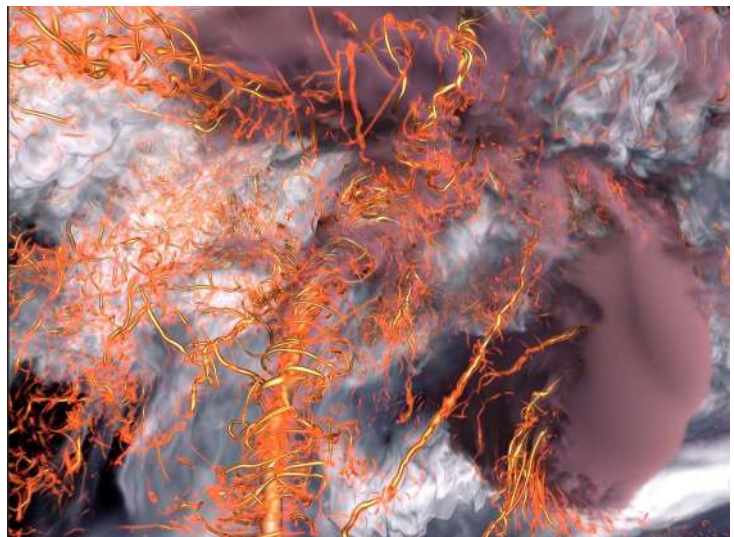

Galactic winds — Exploring galactic outflow processes and galactic formation (page 11)

Mars lander — Analyzing retro-propulsion flow physics to land humans on Mars (page 11)

Seismic — Analyzing sub-surface structures for hydrocarbon discovery (page 11)

Supercell tornado — Exploring the behavior of violent weather phenomena to save lives (page 11)

High fidelity visualizations are important but they are only part of the story. Success is a team effort and NVIDIA IndeX incorporates the latest advances in network and cloud technologies to support universal access and the immersive, collaborative experiences that can lead to breakthough discoveries.

This document focuses on how teams are already using NVIDIA IndeX to unlock value and advance science:

- *Scale* (page 3) — Visualizing a complete and accurate picture of massive data

- *Discover* (page 5) — Rendering interactively for deep understanding and insight

- *Accelerate* (page 8) — Compressing the time to discovery

Next steps (page 10) suggests simple ways you can start your journey of discovery using NVIDIA IndeX.

2   Soaring high

Teams are very successful in creating ever-larger datasets but they struggle to visualize them. The fallback is to visualize partial datasets but the results are unsatisfactory for two key reasons. First, partial visualizations lack context. Second, partial visualizations lack accuracy and precision because they fail to correctly account for neighbouring data.

To address this complex engineering challenge, NVIDIA IndeX was designed from the ground up for successful visualization of the most massive data. Scaling capabilities of NVIDIA IndeX are performance-tested for a range of configurations from a single workstation with a single GPU to multi-GPU, multi-node configurations to ensure optimal performance and the highest visual fidelity.

Teams can rely on NVIDIA IndeX to meet any scaling challenge and generate a complete picture of their data at the original resolution. Because visualizations are complete, precise and accurate, teams can have confidence in their observations, conclusions, and follow-up actions.

The following figure represents the visualization, at the original resolution, of complete seismic datasets using NVIDIA IndeX.


Seismic dataset showing reflectivity and seismic layers using a non-local shading technique (page 11)
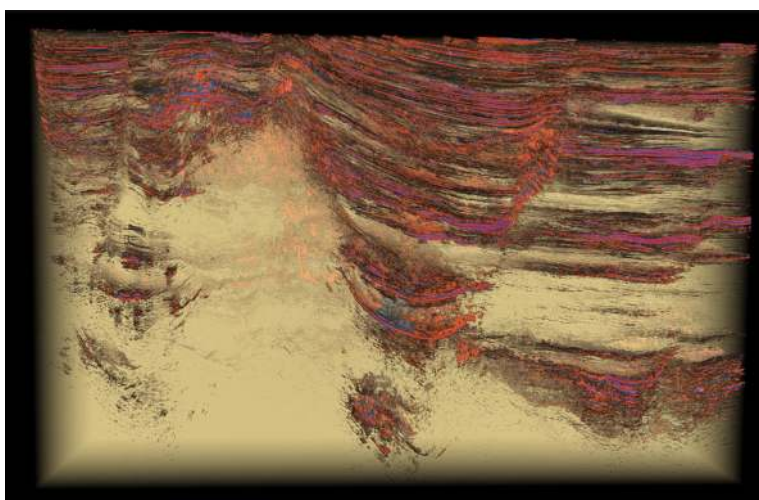
Parihaka dataset showing seismic layers of a large-scale dataset with high and low reflectivity isosurfaces (page 12)

Fig. 2.1 - Overview visualizations of two seismic datasets generated with NVIDIA IndeX using different visualization techniques

Figure 2.2 shows horizons (height fields) generated from the Parihaka dataset. Because the imagery is generated from the complete dataset, analysts can more accurately identify the anomalies that may indicate the presence of hydrocarbon deposits.
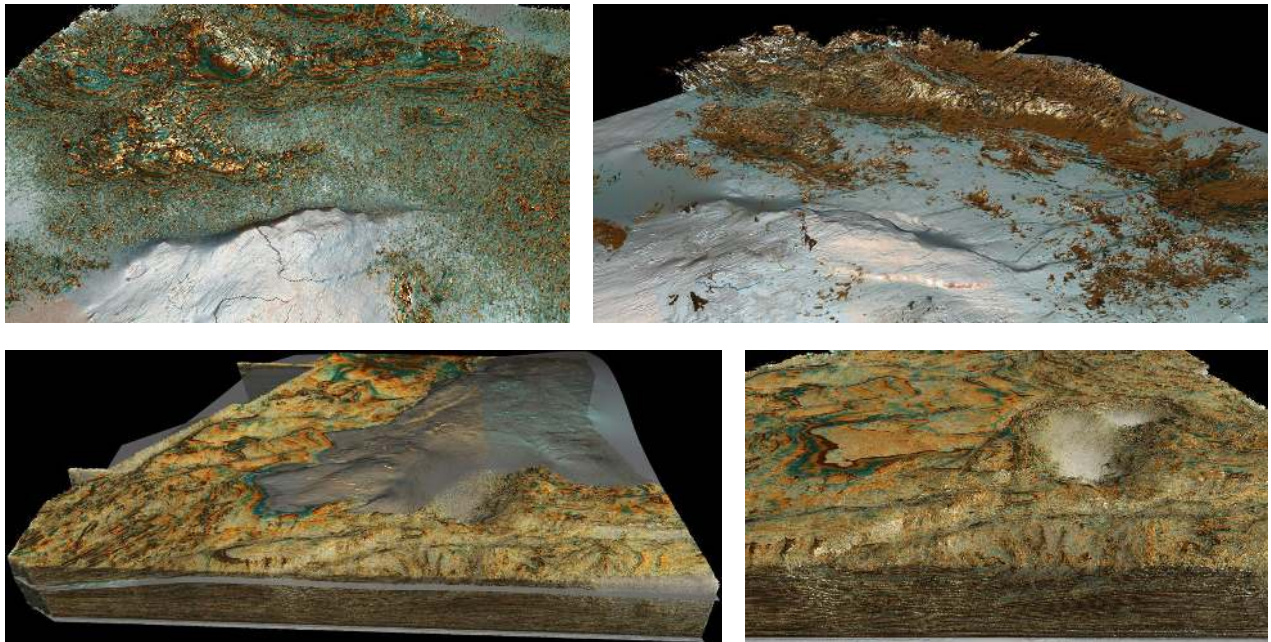
Fig. 2.2 - Example visualizations for combining volume rendering with advanced lighting, high reflectivity isosurfaces (in brown), horizons generated from the Parihaka datasets (page 12)

For energy companies, the value of NVIDIA IndeX is transformational: reduced exploration risks, a smaller environmental impact, and significant savings in time and money.

3 Diving deep

Accelerating understanding and insight places premium importance on interactive exploration and analysis and granular visual control. NVIDIA IndeX introduces NVIDIA IndeX Accelerated Compute (XAC) sampling programs to provide the interactive, low-level control of rendering that deep dives demand. Using XAC programs as volume shaders, teams can control all aspects of rendering — including geometry, lights, materials, and the camera — to modify the appearance of a region of interest. To help teams get started, a set of predefined sampling programs is provided for surfaces and volumes.

The imagery in Figure 3.1 was generated using a XAC-based shader with precomputed ambient occlusion developed in cooperation with the Brazilian Synchrotron Light Laboratory (LNLS/LNBio/CNPEM). The shader facilitates data handling, exploration and semantic sample analysis — just seconds after the data is acquired at the beamline. The imagery represents the internal volumetric visualization of the left ventricle of a heart sample from a mouse. The left ventricle is anatomically dissected and contrast-enhanced for absorption-based synchrotron tomography at MOGNO beamline (Sirius).
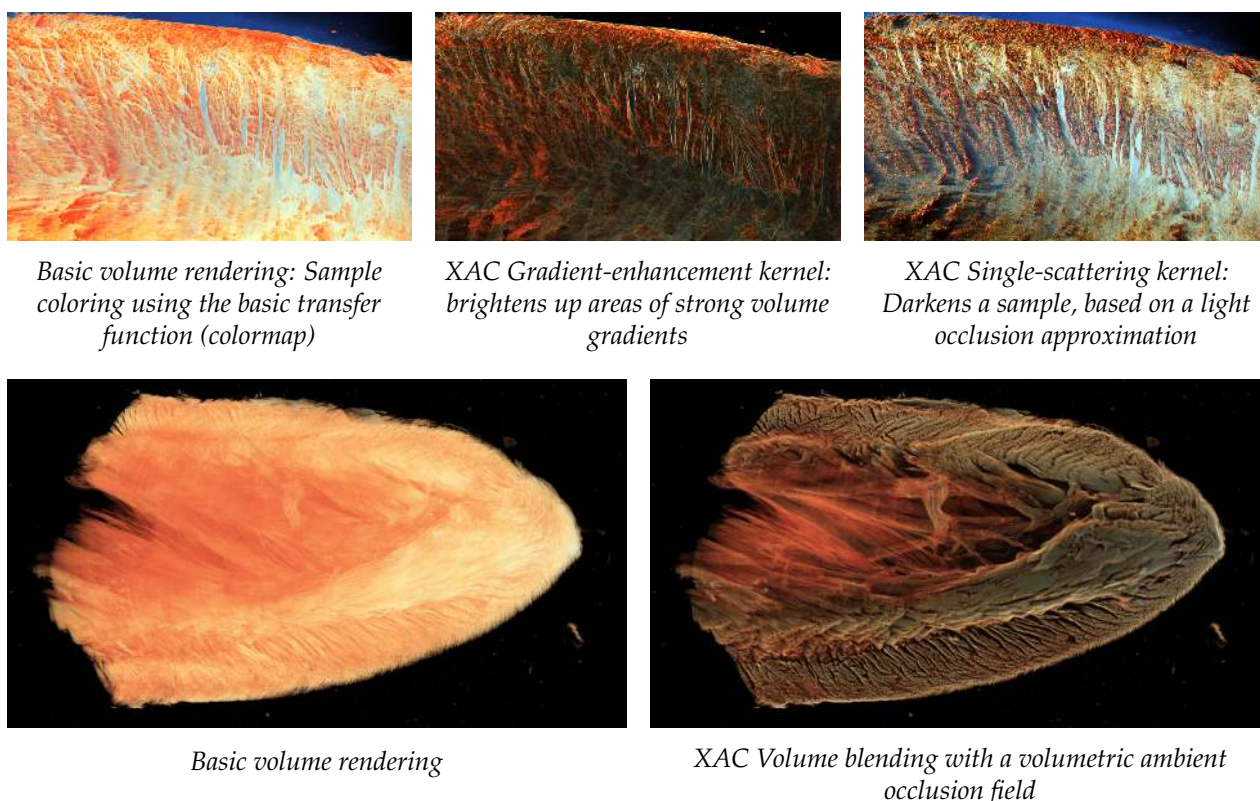

Basic volume rendering: Sample coloring using the basic transfer function (colormap)

XAC Gradient-enhancement kernel: brightens up areas of strong volume gradients

XAC Single-scattering kernel: Darkens a sample, based on a light occlusion approximation

Basic volume rendering

XAC Volume blending with a volumetric ambient occlusion field

Fig. 3.1 - The XAC-based shader for data exploration and visual analysis of a mouse heart sample (page 12)

Figure 3.2 (page 6) is an example of a XAC-based shader developed by LNLS/LNBio/CNPEM for analysis of soil datasets:
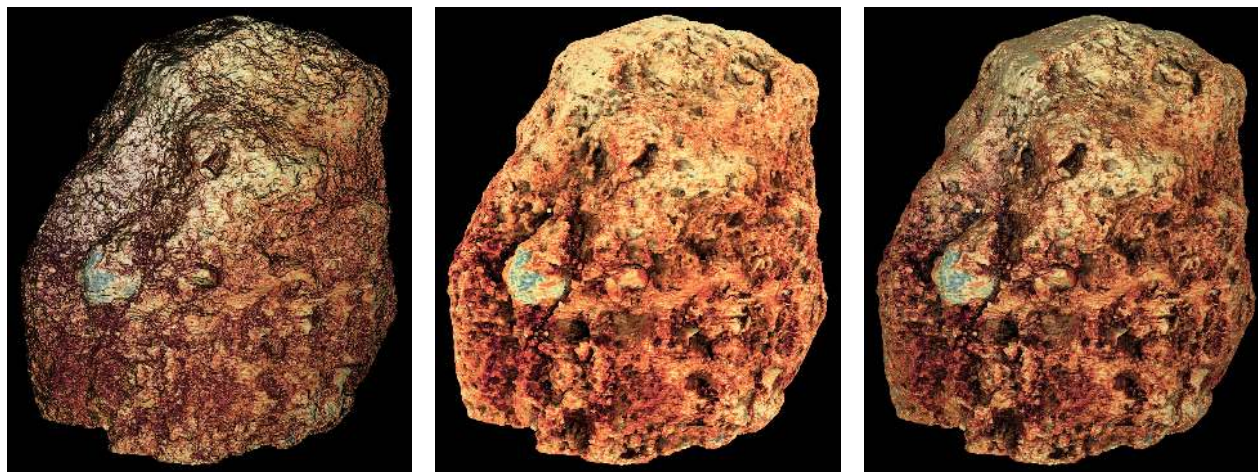
| *XAC Basic shading: Local shading based on volumetric isosurface normals* | *XAC Ambient occlusion: Precomputes light occlusion into all directions* | *XAC Ambient occlusion combined with basic local shading* |

Fig. 3.2 - XAC-based shader for data handling and analysis of soil datasets (page 12)

Teams can use predefined XAC programs as-is and change parameters on the fly. XAC programs are easy to customize using the provided CUDA editor. Programs have a clear three-part structure to simplify editing and the creation of new XAC programs.

Figure 3.3 shows two images generated from a galactic wind simulation where the team used XAC programs for low-level rendering control during discovery.
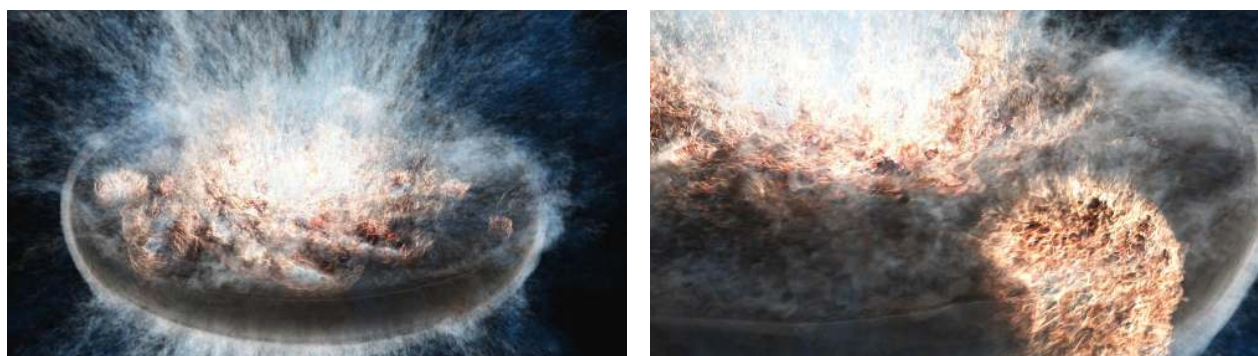

Fig. 3.3 - Visualizing a galactic wind simulation using the XAC Gradient-enhancement kernel to highlight the spatial structure and density distribution around collapse events (page 11)

In Figure 3.3, the high-speed, high-temperature gas (blue) is ejected after mixing with the cooler, denser gas (red) in the galaxy disk. To gain a deeper understanding about how this works, the team used the simulation to clarify the relationships between gas in different phases of galactic outflow.

Initially, the team use aggregate statistics of the generated data for relatively simple analyses. This approach limited the understanding that could be extracted from the data.

Subsequently, the team used NVIDIA IndeX for visual discovery. XAC programs, as shown in Figure 3.4 (page 7), enabled the team to examine in exquisite detail, complex features such as the small, dense clouds embedded in the wind and to inspect the structure of outflows by using fly-throughs of the density field at a single point in time.
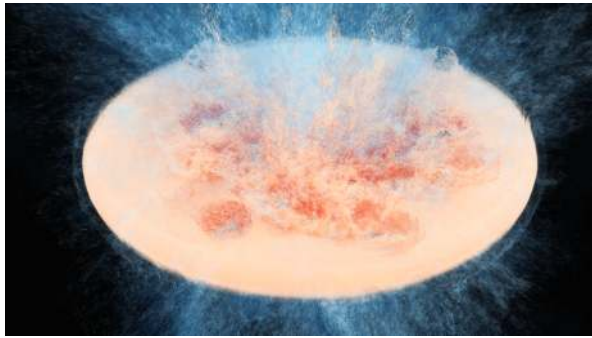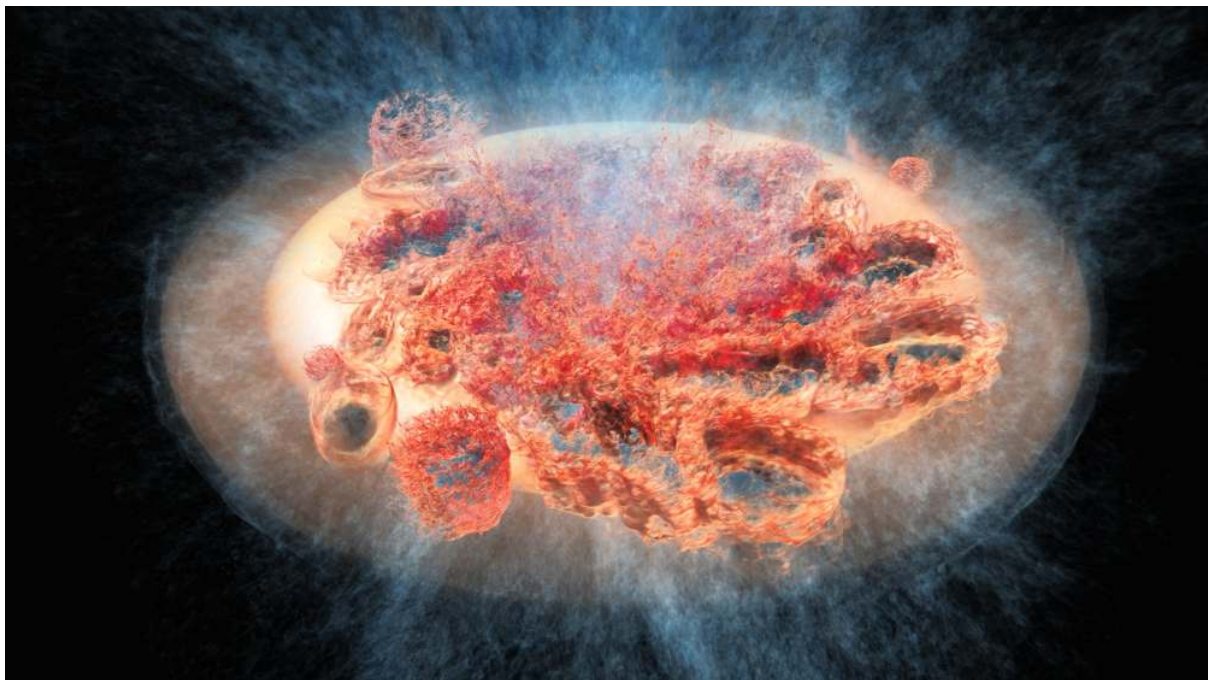
Basic volume rendering of the density field
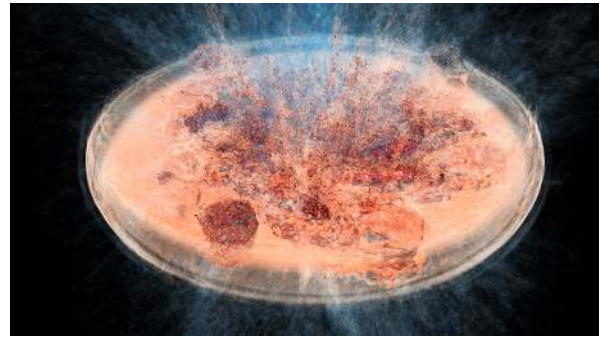
XAC Basic rendering with local shading of selected isosurfaces to highlight selected density levels

XAC Gradient-enhancement kernel to highlight strong changes in the density field

XAC local ambient occlusion filter combined with local shading to emphasize structure and shape of volume features

XAC local ambient occlusion filter with modified transfer function (colormap)

Fig. 3.4 - XAC-based shader for analyzing the detail of complex features in a galactic outflow simulation (page 11)

XAC programs transformed discovery for the team, enabling the fine-grained visual control that accelerates deep understanding and insight.

4 Re-imagining workflows

NVIDIA IndeX is the leader in innovative workflow solutions for accelerated visualization and discovery. Whether a team wants to integrate NVIDIA IndeX into its existing workflow, support immersive collaboration, or compress the time to visualization, NVIDIA IndeX is the go-to solution:

Seamless integration

NVIDIA IndeX offers a C++ library designed for efficient integration into existing workflows. For example, the NVIDIA IndeX for Paraview plugin[1] enables teams to use a familiar toolset for analysis while enjoying the advantages that NVIDIA IndeX has to offer:
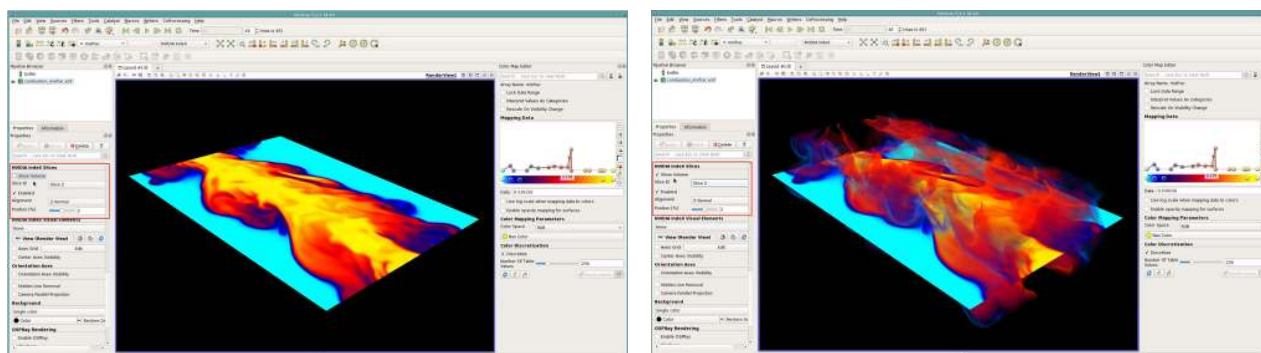

Slice

Slice and volume

Fig. 4.1 - NVIDIA IndeX in ParaView plugin

Immersive collaboration

Discovery can require input from experts around the world. To facilitate remote, immersive collaboration, NVIDIA IndeX offers solutions for public, private, and hybrid clouds. Accelerated compute, rendering, and streaming are managed in the cloud while team members collaborate interactively from any device with an installed browser — anywhere, anytime.
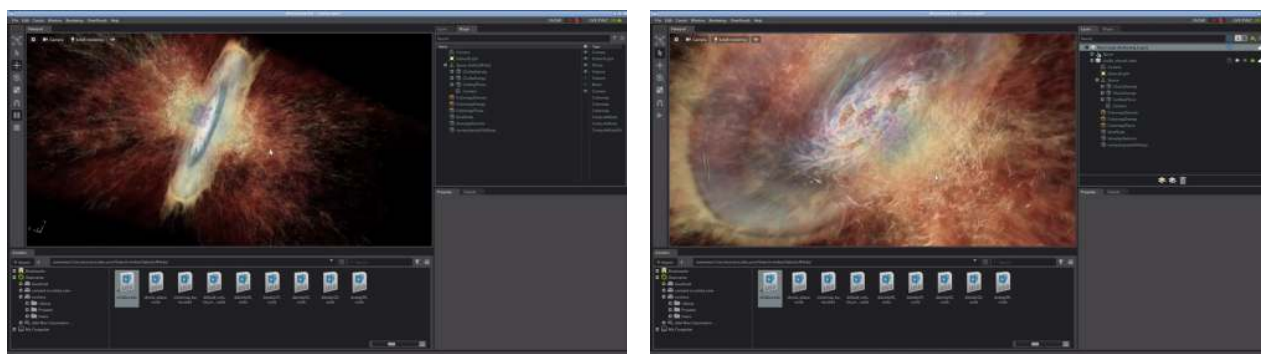
Fig. 4.2 - Team members collaborating from any device with a browser installed

---

1. https://www.nvidia.com/en-us/data-center/index-paraview-plugin/

Accelerated workflow

Supporting a scalable pipeline that can compress the time to visualization is key to accelerating discovery for large-scale science. NVIDIA IndeX offers solutions that parallelize simulation and visualization workflows, while supporting interactive discovery in real time. Teams can steer a simulation by changing input values and immediately view the results. NVIDIA IndeX enables teams to completely reimagine their workflow and implement a scalable *visual simulation* pipeline.

Figure 4.3 shows two images generated from a NASA simulation that explores the requirements for landing humans on Mars. Because test flights are not a realistic possibility, the mission is essentially reliant on simulations.

Shows the vorticity field beneath the lander and how it wraps around the vehicle

Clipped image highlights hydrogen in the range from 0 (red) to 0.002 (blue). The molecular hydrogen distribution through the field is also visible on the surface of the lander

Fig. 4.3 - Mars lander simulation (page 11)

Entry, descent, and landing — or EDL as it is commonly referred to — is the shortest and most intense phase of any mission. However, landing humans on Mars is particularly challenging given the payload and the thin Martian atmosphere so the lander engines will retro-propulsion for the first time ever.

To advance their understanding of retro-propulsion flow physics during EDL, the team is adding atmospheric chemical species to their simulations. This will give the team a better understanding of real gas effects on the retro-propulsion system.

To accelerate the workflow, the team is using NVIDIA IndeX to develop an in-situ pipeline to parallelize simulation and visualization. To make the results easily accessible to the wider scientific community, the team is considering the use of the new NVIDIA Omniverse™[2] platform.

---

2. https://developer.nvidia.com/nvidia-omniverse-platform

5 Next steps

Following are some suggestions about how your team can start using NVIDIA IndeX and accelerate discovery:

Try out NVIDIA IndeX as a cloud service

NVIDIA IndeX is currently available as a cloud service from AWS.[1] The accompanying documentation[2] guides you through the process of setting up a cluster, uploading data, rendering, and viewing results. Example datasets that you can use are available from the Sample Dataset Information[3] page. Instructions are also provided for uploading and rendering your own datasets.

Install NVIDIA IndeX locally and start exploring its capabilities

Fill in and submit the IndeX contact[4] form. You will be given instructions for downloading NVIDIA IndeX.

Try out the NVIDIA IndeX for ParaView plugin

An NVIDIA IndeX plugin is available for ParaView. For more information about the capabilites of the plugin, see the NVIDIA IndeX for ParaView plugin[5] web page. You will find download links at the bottom of the web page.

NVIDIA IndeX is coming to Omniverse

NVIDIA Omniverse is a new simulation and collaboration platform from NVIDIA. Join the beta and get the latest news on the imminent release of the Omniverse ParaView Connector[6] which will include support for NVIDIA IndeX.

For more information about NVIDIA IndeX, see the Getting Started[7] and the NVIDIA IndeX 3D Volumetric Visualization Framework[8] web pages.

For any additional questions you may have, contact the IndeX team at `nvidia-index@nvidia.com`.

---

1. `https://aws.amazon.com/marketplace/pp/prodview-jungamkavzpw2`

2. `https://github.com/NVIDIA/nvindex-cloud/blob/master/doc/eks.md`

3. `https://github.com/NVIDIA/nvindex-cloud/blob/master/doc/datasets.md`

4. `https://developer.nvidia.com/index-contact`

5. `https://www.nvidia.com/en-us/data-center/index-paraview-plugin/`

6. `https://blogs.nvidia.com/blog/2021/04/13/omniverse-paraview-connector/`

7. `https://developer.nvidia.com/nvidia-index-get-started`

8. `https://developer.nvidia.com/nvidia-index`

6 Credits

A special thanks to the following researchers, institutes, and enterprises whose work is featured in this document:


Evan Schneider/Princeton University and Brant Robertson/UC Santa Cruz. Using an ORNL INCITE allocation on the Titan supercomputer, the Cholla Galactic OutfLow Simulations (CGOLS) suite was used to simulate galactic winds on scales of approximately 10 kiloparsecs with a resolution of approximately 5 parsecs. This represented an order of magnitude higher resolution than had ever been used to simulate a single galaxy.


Eric Nielsen and Ashley Korzun et al., Computational AeroSciences Branch, NASA Langley Research Center and Dr. Patrick Moran, Advanced Supercomputing Division, NASA Ames Research Center. Dr. Moran provides high-fidelity visualization support for large-scale simulations performed for a broad range of NASA projects. Dr. Moran will help produce images and animations necessary to support the current scientific goals and devise new approaches for data analysis to extract new physical understanding.
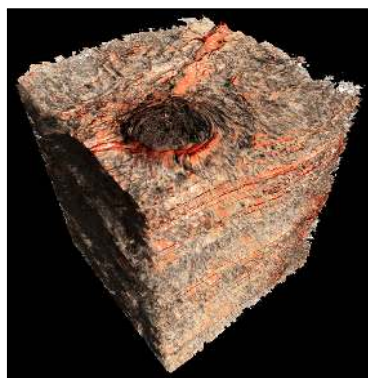
Shell International Exploration and Production B.V. for providing a rendering of a seismic dataset visualized with NVIDIA IndeX. The company serves clients worldwide, providing exploration, extraction, and processing of gas, oil, and other products.
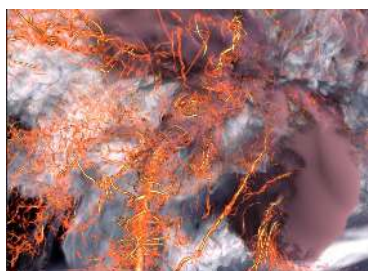
Prof. Leigh Orf, Atmospheric Scientist with the Cooperative Institute for Meteorological Satellite Studies (CIMSS) and Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison. Image captured from from a mathematically-derived, real-time simulation of a tornado using the initial conditions just before the tornado formed.
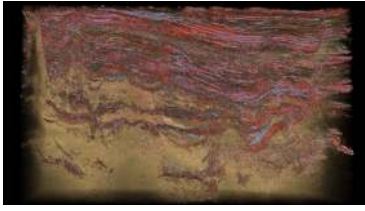
Crown Minerals and the New Zealand Ministry of Economic Development for permission to visualize this Taranaki Basin dataset. Crown Minerals manages the New Zealand Government's oil, gas, mineral and coal resources.

The LNLS/LNBio/CNPEM imaging project, with special thanks to Mogno beamline, Scientific Computing Group, and LNBio for the XAC presets.