

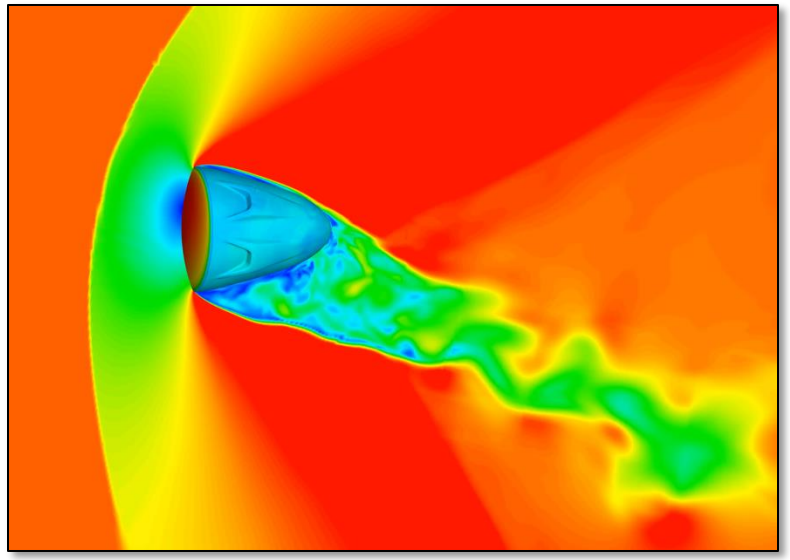
National Aeronautics and
Space Administration

High-End Computing Enables Discovery at NASA

William Thigpen
NASA Ames Research Center
April 9, 2025

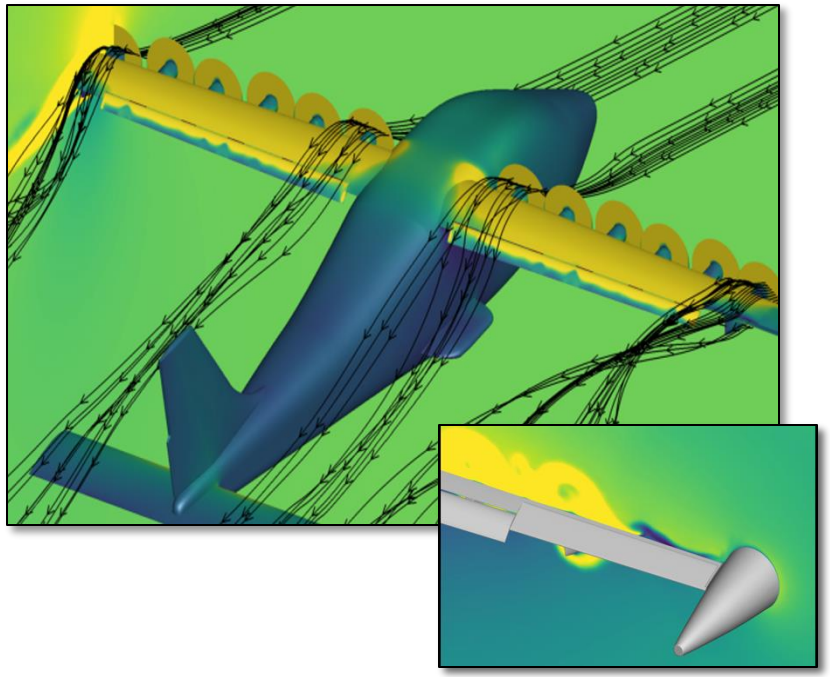
NASA's HEC Requirements: Capacity

- Engineering-related work requires HEC resources that can handle large numbers of jobs with quick turnaround times.



The teams at NASA Johnson and NASA Ames ran thousands of CFD solutions on HECC computing resources available at the NASA Advanced Supercomputing facility at Ames Research Center, along with the NASA Johnson Europa supercomputer, to show that these vehicles will meet their mission objectives

Over 295,000 Broadwell-equivalent node hours were used on meshes up to 350 million cells, which required up to 1,000 CPUs per solution

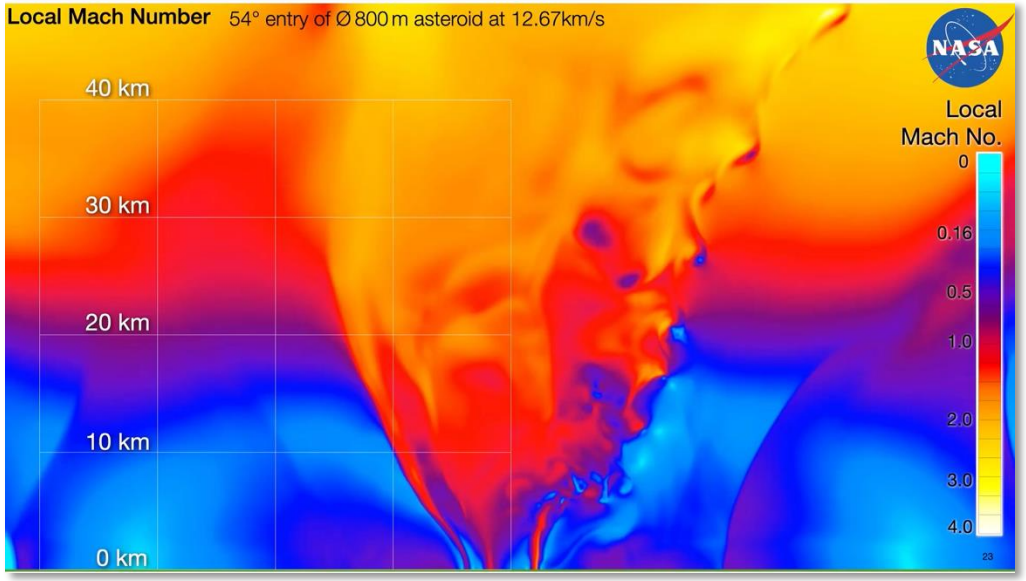


Leveraging HECC GPU resources has been a breakthrough, making it possible to apply wall-modeled scale-resolving simulation techniques to improve predictive capabilities

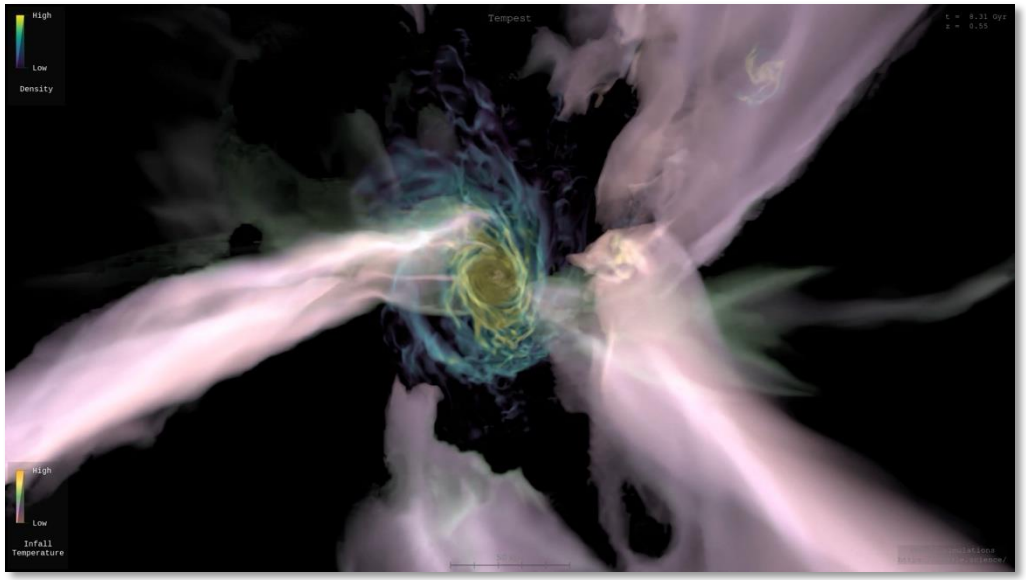


NASA's HEC Requirements: Capability

- Aeronautics and science related work require HEC resources that can handle high fidelity relatively-large CPU-count jobs with minimal time-to-solution. Capability enables work that wasn't possible on previous architectures.



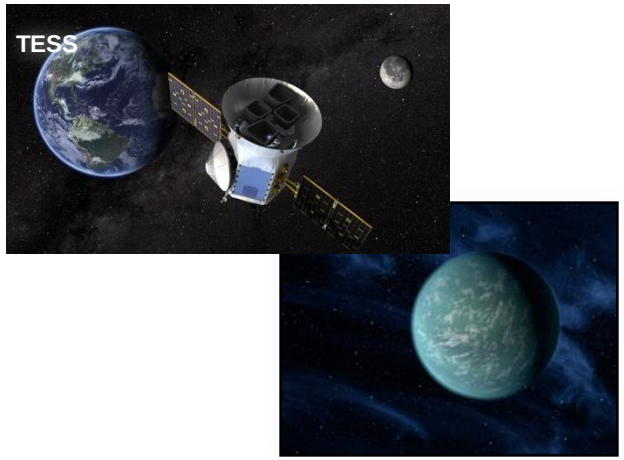
Simulations run on HECC supercomputers examining potential damage from asteroids used between 4,000–40,000 processors for each run and took from 10 hours to several weeks to complete.



The FOGGIE simulations requires significant computing power. Each of the six galaxies simulated in the FOGGIE suite is run on 512 nodes on Pleiades and takes 12–18 months of wall-clock time (several million node-hours).

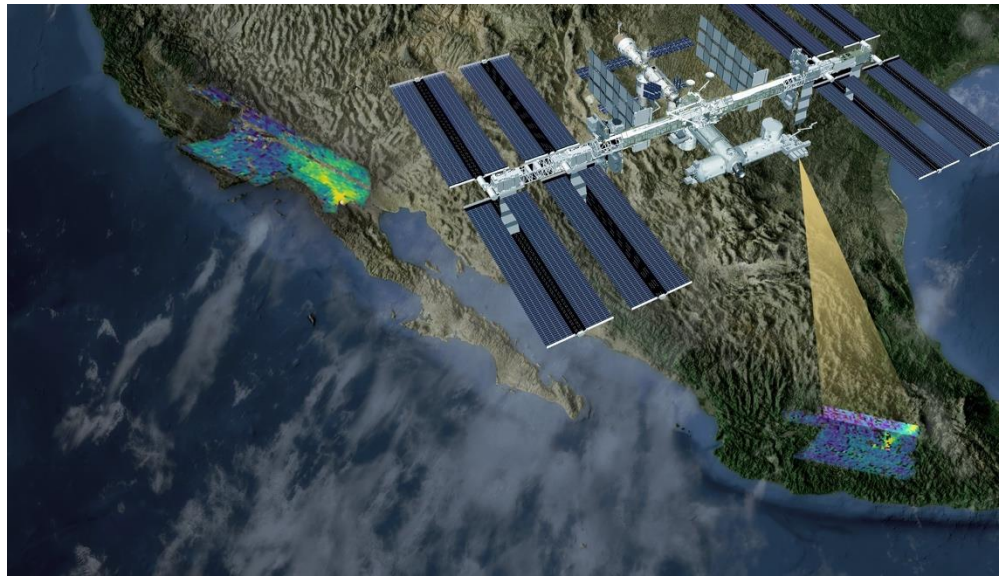
NASA's HEC Requirements: Time Critical

- NASA needs HEC resources that can handle time-sensitive, mission-critical applications on demand (maintain readiness).



HECC worked with TESS to design a data pipeline that incorporated lessons learned from earlier missions enabling enormous planetary transit searches to be completed in less than a day with accuracy and effectiveness of the software pipeline.

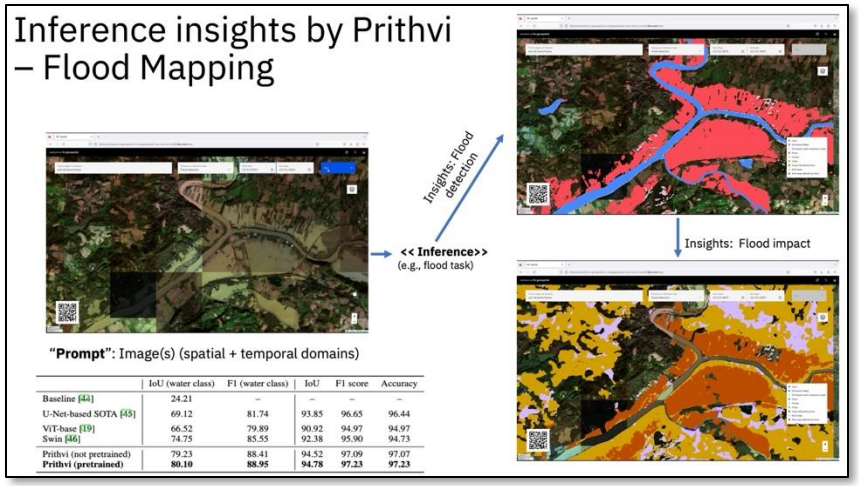
At 9:48 am PDT on 2 November 2024 the TESS Science Processing Operations Center (SPOC) was notified about a gamma ray burst, GRB 241030A, that had been observed by TESS in the first half orbit of sector 85 that would be downlinked through the DSN that evening. The SPOC was able to retrieve, process and stage data for Camera 3 CCD 3 containing the full gamma ray burst that was first triggered by the Fermi Gamma-ray Burst Monitor (GBM) at 05:48:03 UT on 30 Oct 2024. TESS completed the downlink and stage the entire level 0 full frame image (FFI) dataset by 7:30 pm PDT, and the SPOC was able to retrieve, process and calibrate the FFIs within 11 hours by 5:20 AM PST on 3 November 2024. The data for camera 3 CCD 3 were staged on the NAS Data Portal and released to the public shortly before 6 am PST on 3 November 2024.



The OCO-2/3 missions collect millions of soundings over the Earth every day. Pleiades' Broadwell and Haswell nodes are critical for timely processing and provide crucial CO_2 data to the research and application communities..

NASA's HEC Requirements: Artificial Intelligence

- NASA needs HEC resources that can enable discovery through the use of computers to explore massive data sets.



	IoU (water class)	F1 (water class)	IoU	F1 score	Accuracy
Baseline [44]	24.21	–	–	–	–
U-Net-based SOTA [45]	69.12	81.74	93.85	96.65	96.44
ViT-base [19]	66.52	79.89	90.92	94.97	94.97
Swin [46]	74.75	85.55	92.38	95.90	94.73
Prithvi (not pretrained)	79.23	88.41	94.52	97.09	97.07
Prithvi (pretrained)	**80.10**	**88.95**	**94.78**	**97.23**	**97.23**

HECC worked with the Earth Science Division in the Science Mission Directorate, the Department of Energy and industry to develop an Earth Science foundation model to do predictions and analysis.



Across NASA, teams are evaluating, testing and utilizing AI for design, scheduling, identifying areas of interest and predicting future states based on current. conditions.

Meeting Today's Requirements

HECC Hardware Assets

5 Compute Clusters

- Aitken — 20 Racks / 3,200 nodes / 13.1 PF / 10,204 SBU/hr
- Pleiades — 144 Racks / 10,310 nodes / 6.83 PF / 7,600 SBU/hr
- Electra — 24 Racks / 3,456 nodes / 8.32 PF / 4,815 SBU/hr
- Cabeus — 40 Racks / 537 nodes / 1,106 GPUs / 17.6 PF / 12,196 SBU/hr
- Endeavour — 2 Racks / 2 nodes / 155 TF / 81.2 SBU/hr

1 Visualization Cluster 1-billion-pixel display / 128 nodes / 2.61 PF

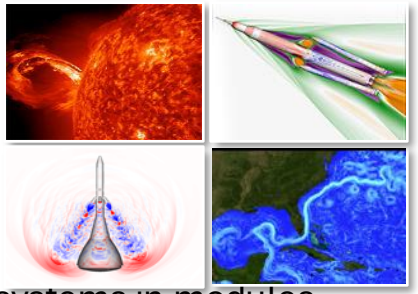
13 Lustre File Systems 118.1 PB

3 NFS File Systems 3.3 PB

2 BeeGFS File Systems 1.5 PB

1 VAST File System 2.5 PB

Archive System 1,572 PB



NAS Facility Extension

- One-acre 30 MW site to house HPC systems in modules.

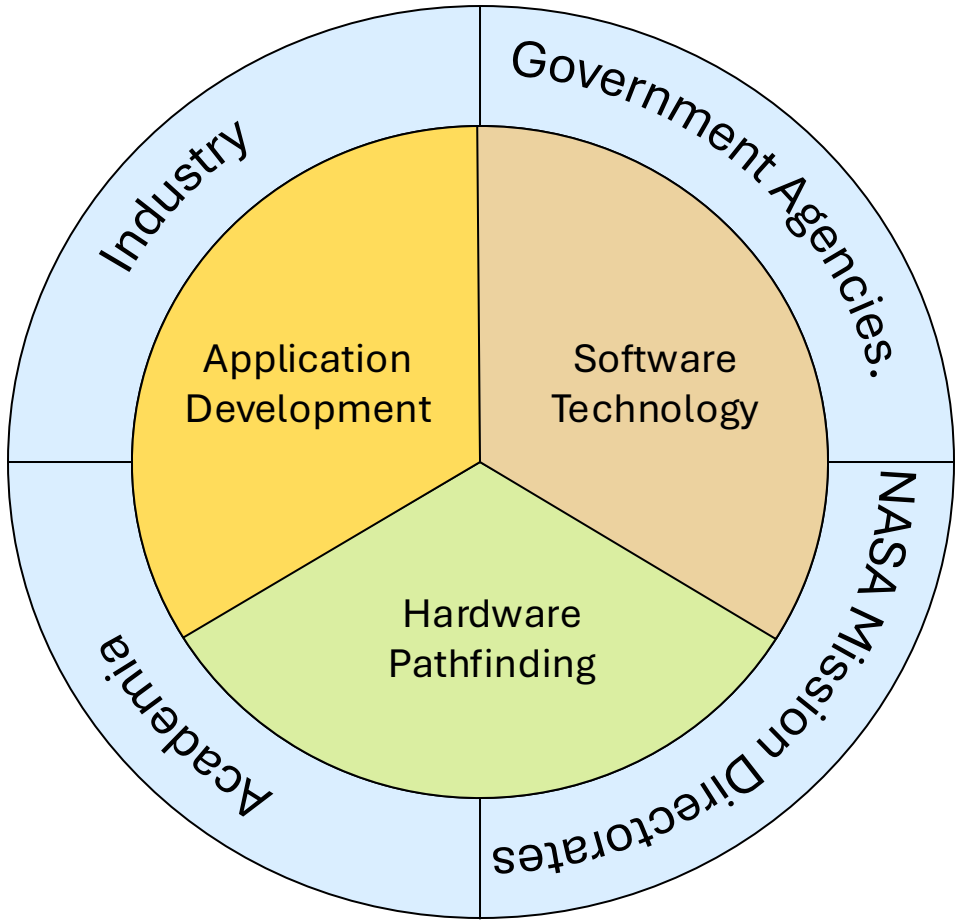
HECC provides a suite of complimentary services to the user community to enhance the scientific and engineering results obtained from the hardware assets.

- Systems: Customized solutions including compute and storage solutions to meet specific project or mission requirements. Cloud access for immediate or non-standard computing.
- Cloud Resources: Customized cloud access for hybrid data pipelines, traditional simulations and exploratory research.
- Application Performance and Productivity: Software solutions provided to research/engineering teams to better exploit installed systems.
- Visualization and Data Analysis: Custom visualization during traditional post-processing or concurrent during simulation to understand complex interactions of data.
- Networks: End-to-end network performance enhancements for user communities throughout the world.
- Data Analytics: Exploitation of data sets through neural nets and emerging new techniques.
- Machine Learning: Custom environments to enable learning through advanced data techniques.
- Custom Data Gateways: Custom data portals to support diverse programs and projects.

Preparing for the Future

- New algorithms to match hardware realities.
- Mixed precision and machine learning/AI in computation.
- New methods in visualization and data analytics.
- Application enhancements to exploit I/O advancements.
- Fault resilience.
- Performance optimization.

- Examine requirements.
- Develop necessary benchmarks.
- Assess I/O approaches.
- Develop models to predict performance.
- Make recommendations for pathfinding systems.



- Research and develop programming approaches, for accelerated and non-accelerated architectures.
- Optimize and port techniques/tools.
- Optimize and port techniques/tools for visualization, data analytics, AI, and machine learning.
- Research and develop efficient math libraries.
- New file system software technologies.
- Research and develop machine learning techniques for problem solving and system error tracking/prediction.
- Evaluate software packaging technology, such as containers.

High-End Computing Capability

The High-End Computing Capability (HECC) project, established in 2008, has a broad vision that spans all NASA mission areas:

> *NASA's HECC resources are relied on as an essential and pervasive partner by the breadth of agency science, engineering, and technology activities, enabling rapid advances in insight and dramatically enhancing mission achievements.*

Toward that vision, FY 24, HECC delivered over 197 million Standard Billing Units (SBUs*)—essential to the success of 783 projects supporting ARMD, STMD, SOMD, ESDMD, HEOMD, NESC, and SMD.

This year HECC also celebrated several major successes:

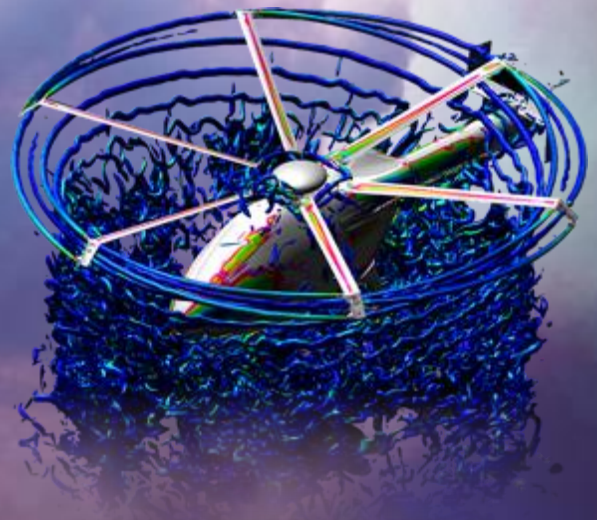
- **Two major expansions of Cabeus**: HECC's first general-use supercomputer consisting entirely of general-purpose graphics processing units (GPGPUs), initially added five petaflops of performance and then an additional 10.2 petaflops to HECC's supercomputing capability.
- **MSF Expansion Continues:** HECC is finishing the installation of the second module of the Modular Supercomputing Facility (MSF) that will house the four AMD Milan racks, and the 20 PF next-generation system being delivered in early July.
- **hyperwall4 fully operational:** The new hyperwall (unveiled in May 2024), HECC engineers and Visualization and Data Analysis experts collaborated with counterparts at Ames completing an extensive remodel of the NAS facility's Visualization Lab and deployed a 1-billion pixel display wall backed by a 128-node GPU cluster allowing for real-time/near-real-time date processing, generation and streaming.





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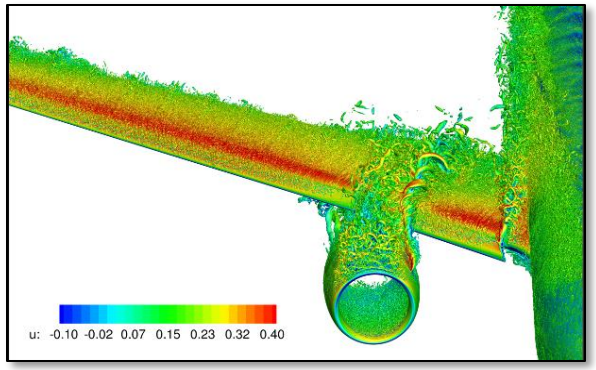




Aeronautics Research Mission Directorate



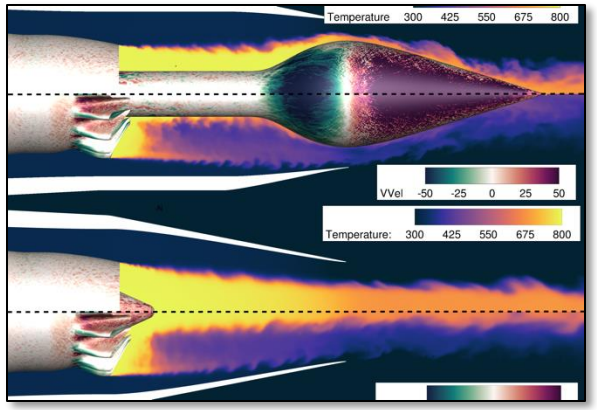
High-End Computing Enables Engineering Excellence



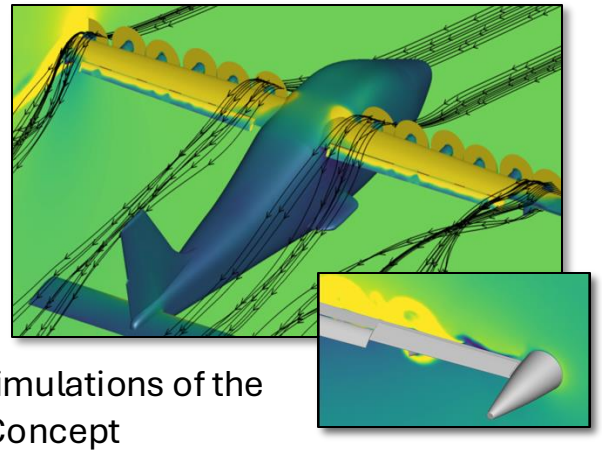
High-Lift Computational Tools for FUN3D



GPU Computing for WMLES Modeling of High-Lift Flows



Aeroacoustic Predictions for Supersonic Jet Noise



High-Fidelity Simulations of the X-57 Maxwell Concept



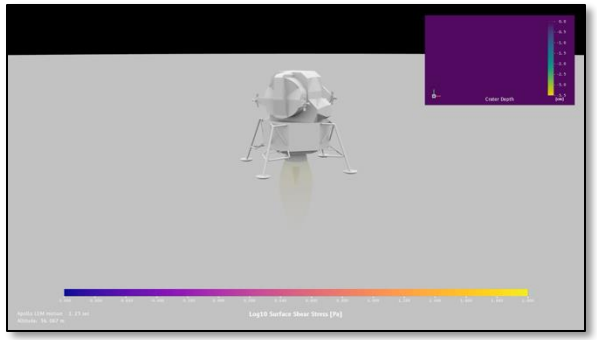
Simulating NASA's Quadcopter in Ground Effect

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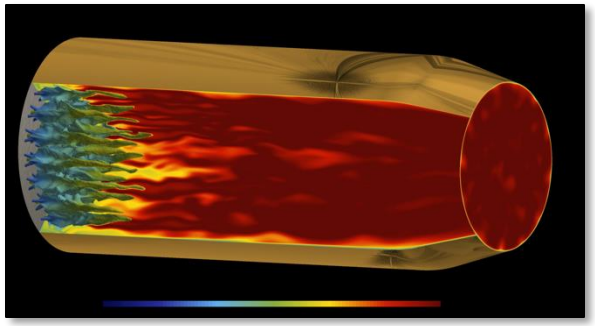
Exploration Systems Development, Space Operations, and Space Technology Mission Directorates



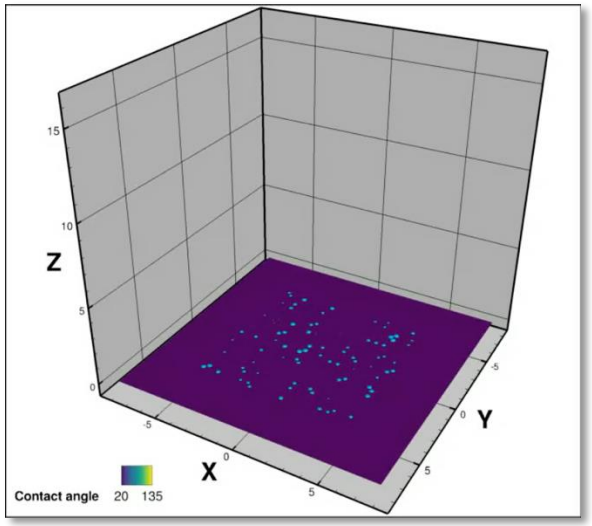
High-End Computing Enables Exploration



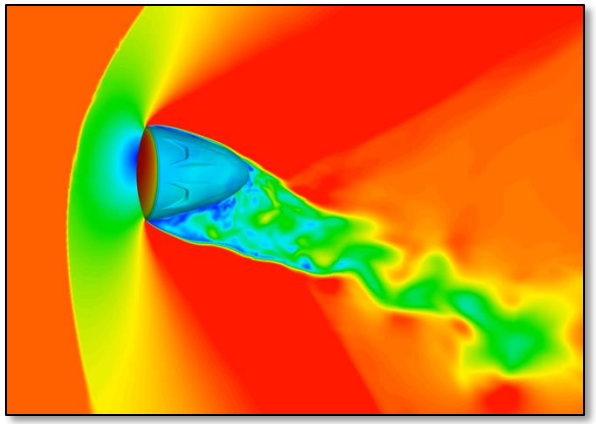
New Tools for Modeling Plume-Surface Interaction



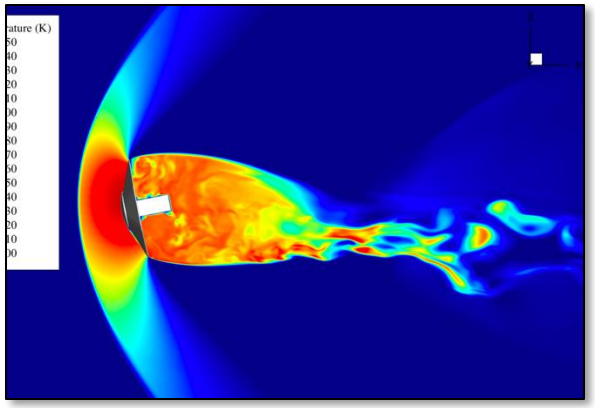
Simulating Combustion for Methane-Oxygen Fuel



Biphilic Surfaces for Electronics Cooling



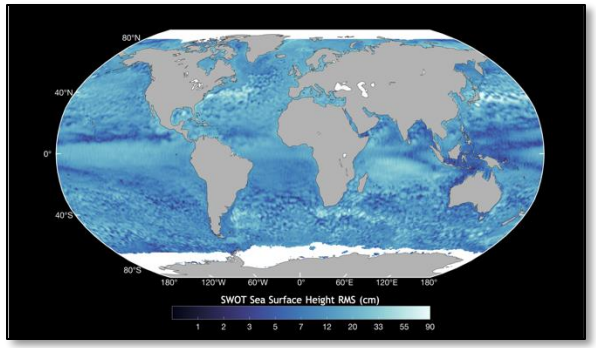
Aerodynamic Analysis for Safe Human Space Flight



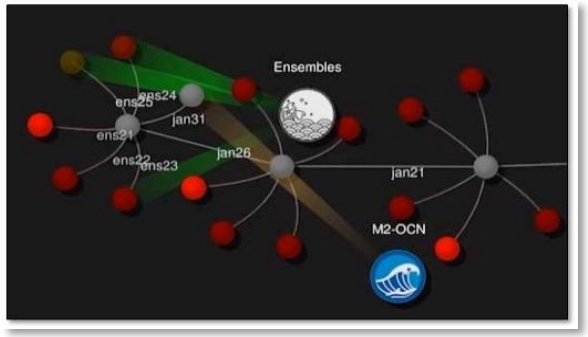
Simulating Capsule Free-Flight for Planetary EDL


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NASA
Science Mission Directorate

High-End Computing Enables Research and Discovery



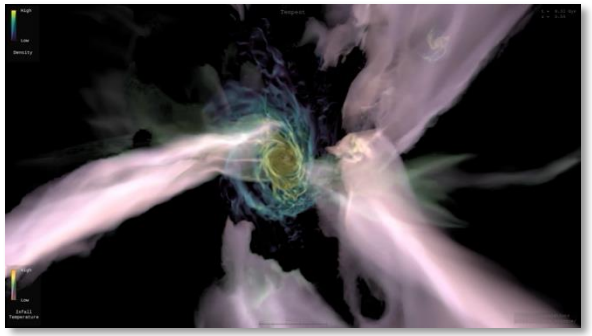
Developing Algorithms and Tools for SWOT



An Innovative Strategy for Ensemble Forecasts



Processing Orbiting Carbon Observatory Data

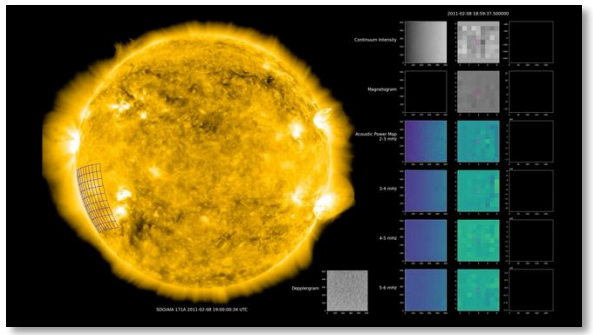


Tracking the Fuel for Galaxy Growth

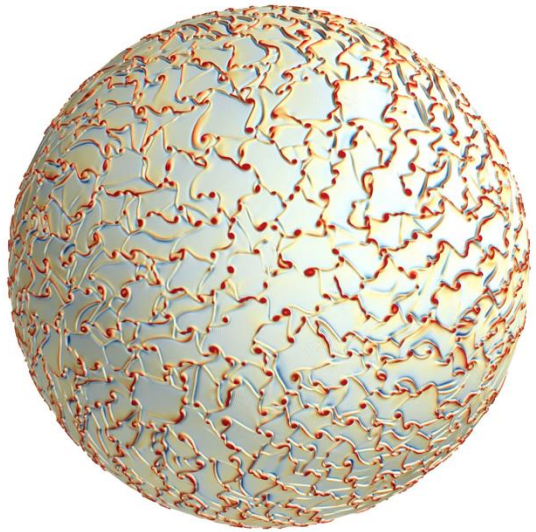


Using Solar Eclipses to Improve Coronal Models

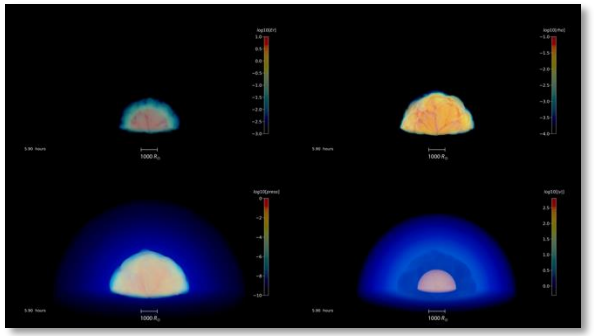
High-End Computing Enables Science



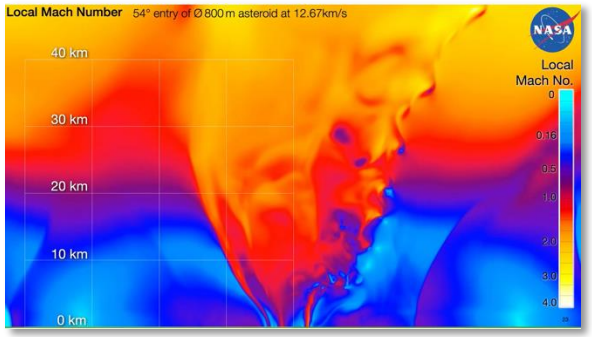
Machine Learning to Predict the Emergence of Sunspots



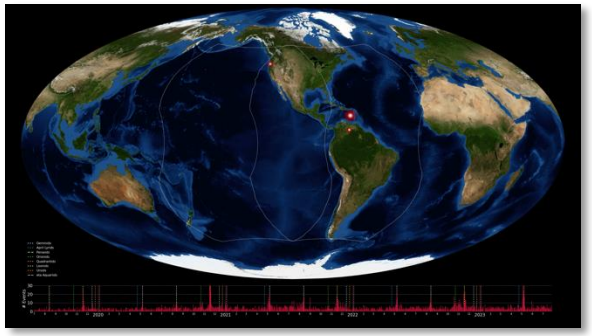
Exploring Dynamics of the Deep Solar Interior



Watching Supernova Shock Breakouts in 3D



Simulating Asteroid Trajectories for Planetary Defense



Finding Fireballs Hidden in Satellite Lightning Data



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