National Aeronautics and Space Administration

HPC to Enable NASA Missions

Rupak Biswas

Director, Exploration Technology Directorate

NASA Ames Research Center, Moffett Field, Calif., USA

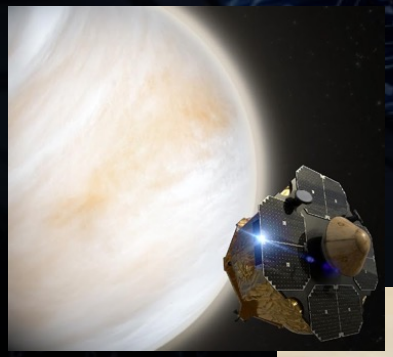
Multicore World XII, Christchurch, NEW ZEALAND

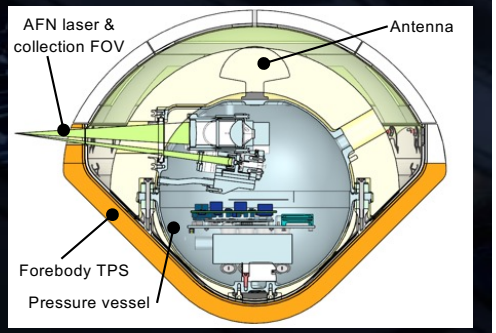
17 February 2025

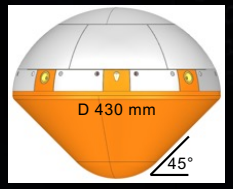
www.nasa.gov

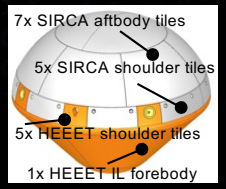
Collaboration with Rocket Lab

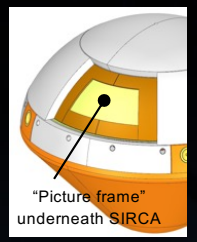
- Venus Life Finder a planned probe to detect signs of life in Venusian atmosphere
  - Research indicates presence of phosphine
- Spacecraft developed by Rocket Lab
  - Photon Explorer cruise stage will send a small atmospheric probe into Venus
  - Probe has autofluorescing nephelometer (AFN) to search for organics
- Launch scheduled in Aug 2026 to LEO on Electron
  - Orbit raising, departure, and deep space cruise with interplanetary Photon
  - Hyperbolic trajectory and direct entry on night side of Venus in Dec 2026
- AFN to measure backscatter and induced fluorescence in cloud layer
  - Only 270 secs to perform all measurements
  - Comm direct to Earth via S-band and DSN
- NASA providing TPS for forebody and backshell
  - Materials are HEEET Insulating Layer and SIRCA
  - Aeroshell recently delivered to RL's Long Beach facility for final assembly
  - Expertise / Support in designing, testing, manufacturing, analyzing, and integrating TPS for Neutron

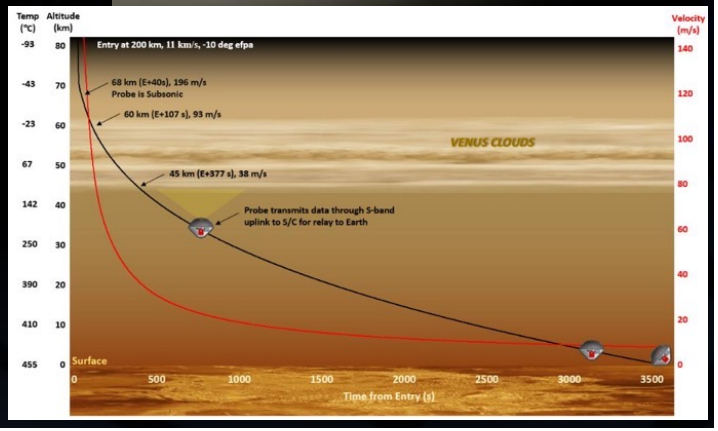










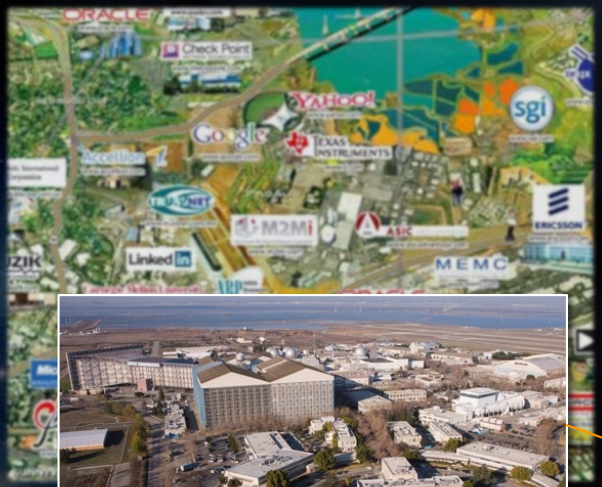


What NASA Does

Conduct world-class science; Inspire current & future generations; Establish national posture that affects humanity's future

Aeronautics Research	Space Operations	Deep Space Exploration Sys.	Science	Space Technology
				
Transform Aviation through R&D	*Launch and Space Operations*	*Moon to Mars Exploration*	*Understand the Sun, Earth, and Universe*	*Develop and transfer space technologies*

NASA Centers



Ames Research Center

Glenn Research Center

HQ

Goddard Space Flight Center

Langley Research Center

Marshall Space Flight Center

Armstrong Flight Research Center

Jet Propulsion Laboratory

Johnson Space Center

Stennis Space Center

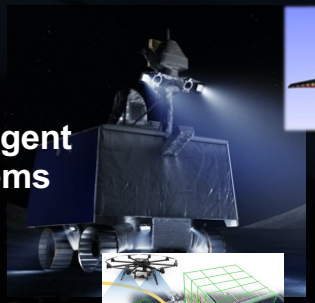
Kennedy Space Center

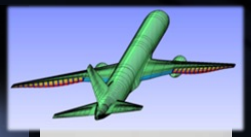
Exploration Technology @ NASA Ames

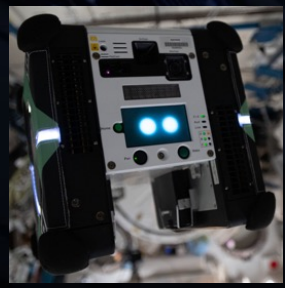
Largest directorate at Ames with over 900 researchers, scientists, engineers, and staff. The four divisions provide leadership in human-centered software solutions, information technology and computational science, supercomputing and other advanced computing, and planetary atmospheric entry systems

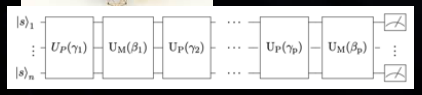
Human Systems Integration

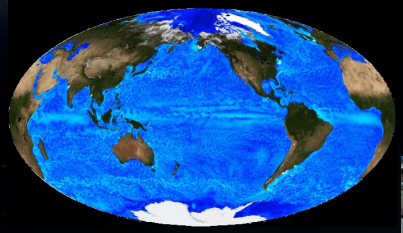
Intelligent Systems

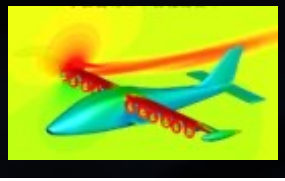






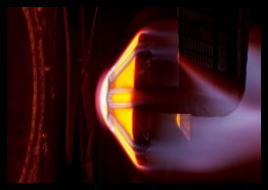


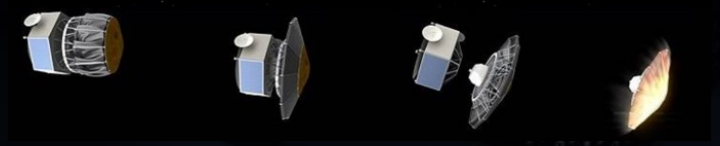




Advanced Supercomputing

Entry Systems & Technology

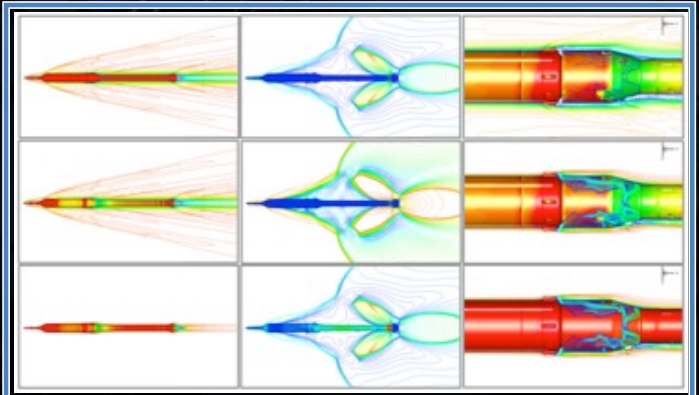




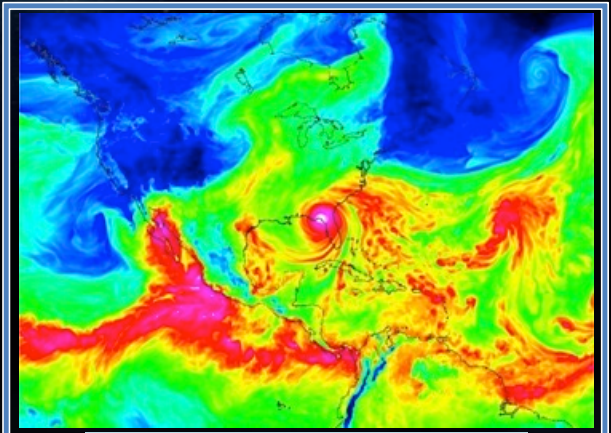
Advanced Computing Environment

NASA's Diverse HPC Requirements

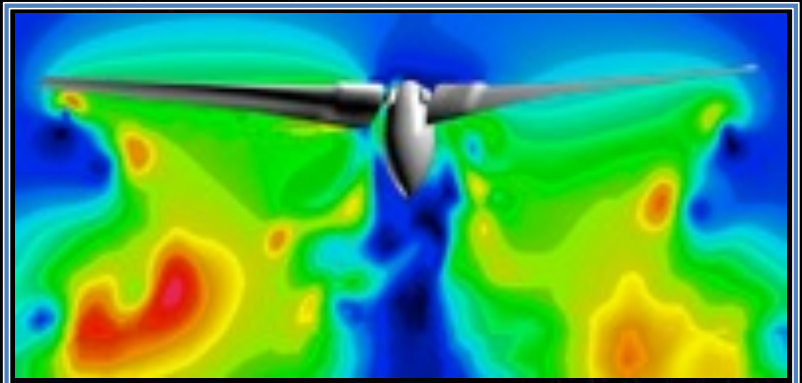
- Engineering requires HPC resources to process large ensembles of moderate-scale computations and data analyses to efficiently explore design space ***(high throughput / capacity)***
- Science requires HPC resources to handle high-fidelity long-running large-scale computations and deep learning to advance theoretical understanding ***(leadership / capability)***
- Time-sensitive mission-critical applications require HPC resources on demand ***(high availability / maintain readiness)***



Aerodynamic database generation

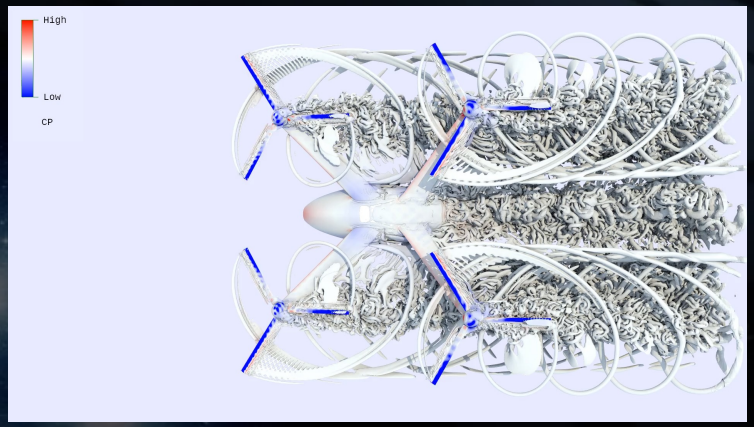


Real-time hurricane prediction

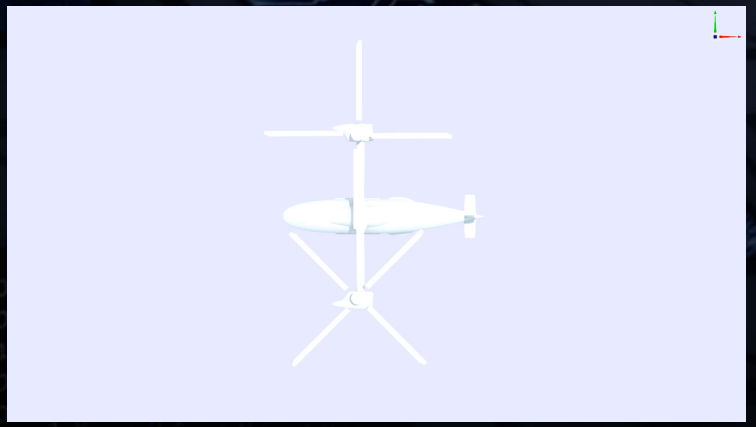


Rotary wing unsteady aerodynamics

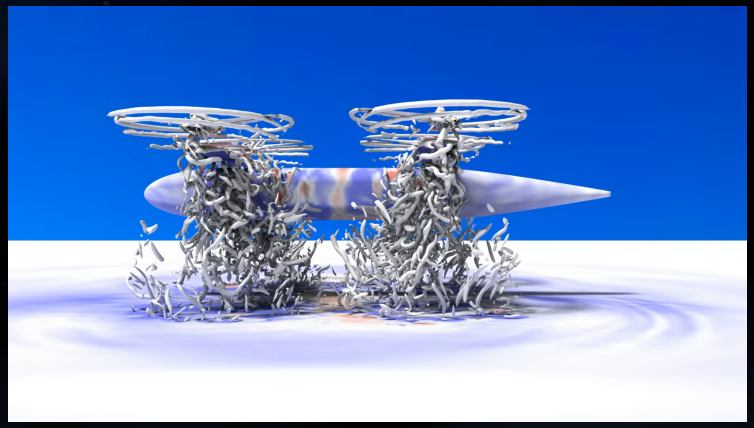
Air Mobility Concept Vehicles



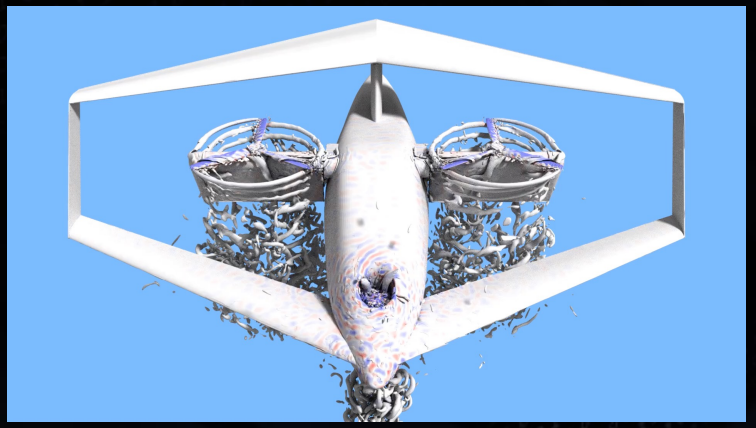
Vertically-separated rotors to reduce drag



Inter-meshing rotors to increase efficiency



Quad tilt rotor



Joined wing to minimize induced drag

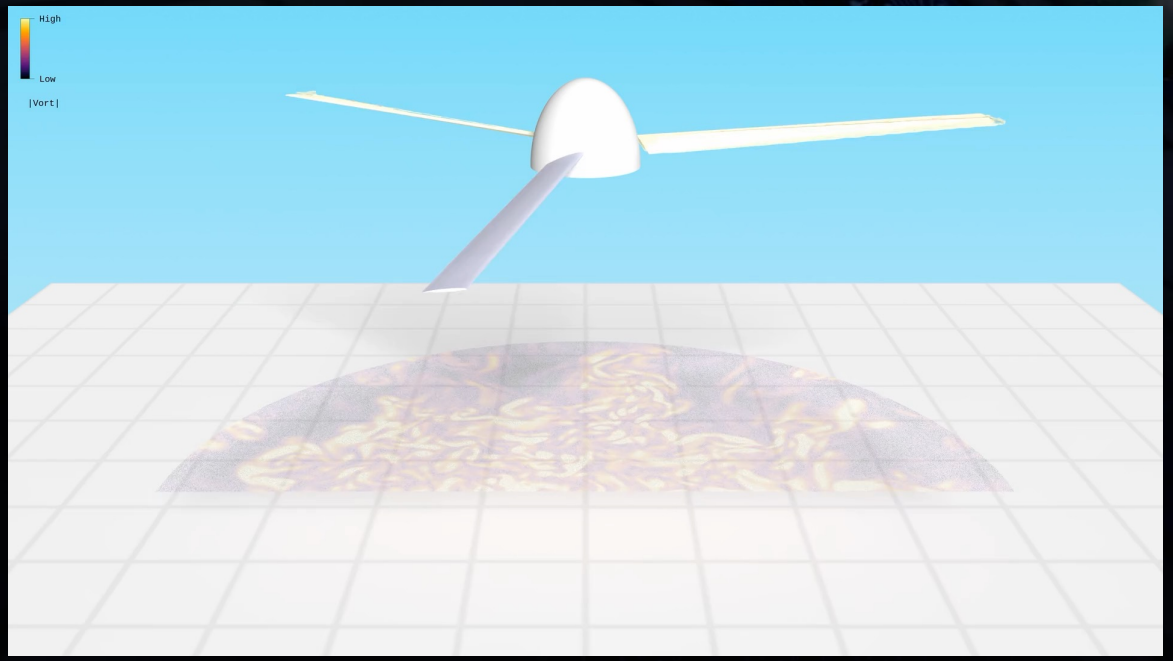
Isolated Rotors in Ground Effect

Development of UAM vehicles by simulating new VTOL designs to ensure safe and efficient operations

CFD simulations of rotors in ground effect

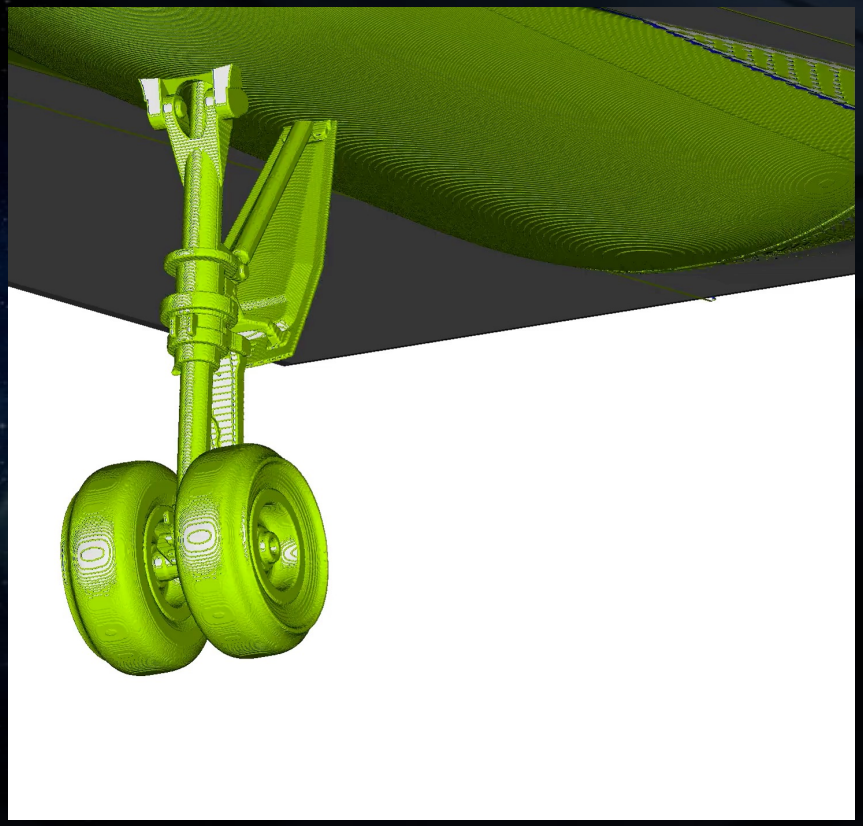
- Addition of ground surface makes simulations significantly more challenging
- Enables better characterization of vehicle aerodynamics in proximity to ground

Simulations identified dangerous areas due to high winds & large gusts



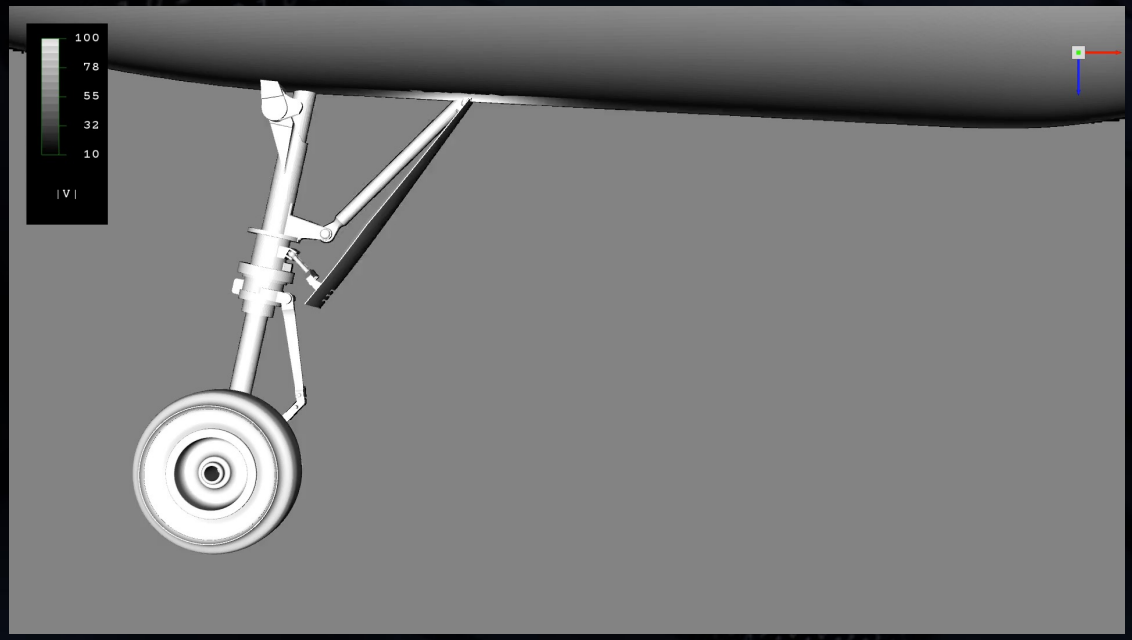
Flow visualization of isolated rotors in hover in ground effect with plane located one radius below rotor

Landing Gear Noise



Simulation using 12 levels of mesh refinement and 1.6 billion cells (iso-contours of vorticity colored by Mach number: blue = 0, red = 0.25)

Centerline slices showing velocity magnitude



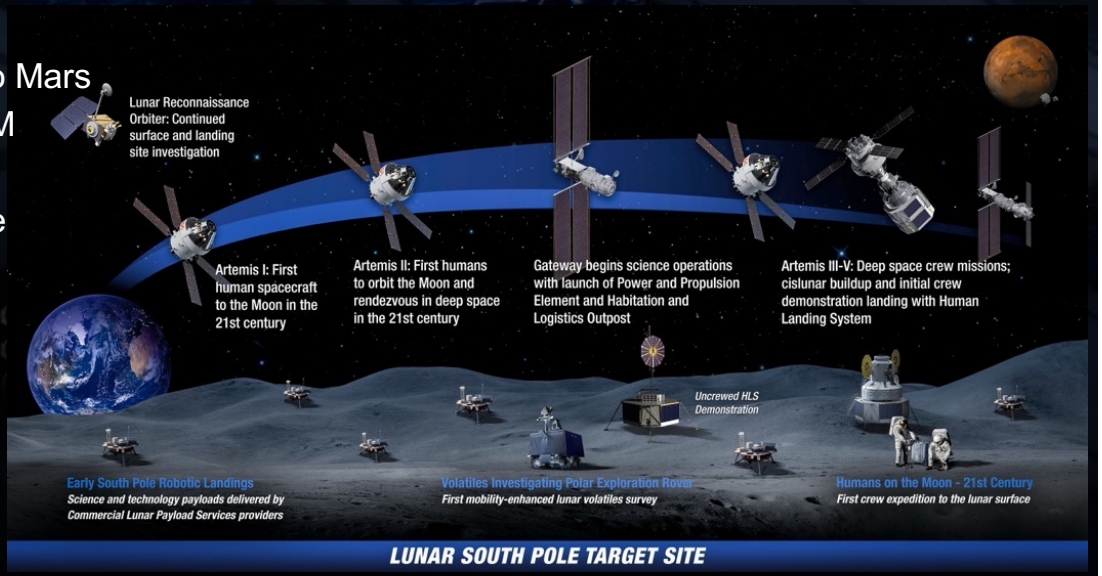
To Moon and Mars

Why go to the Moon?

- Proves technologies & capabilities for sending humans to Mars
- Inspires a new generation & encourages careers in STEM
- Leads civilization-changing science & technology
- Broadens U.S. industry & intl. partnerships in deep space

The Artemis Program

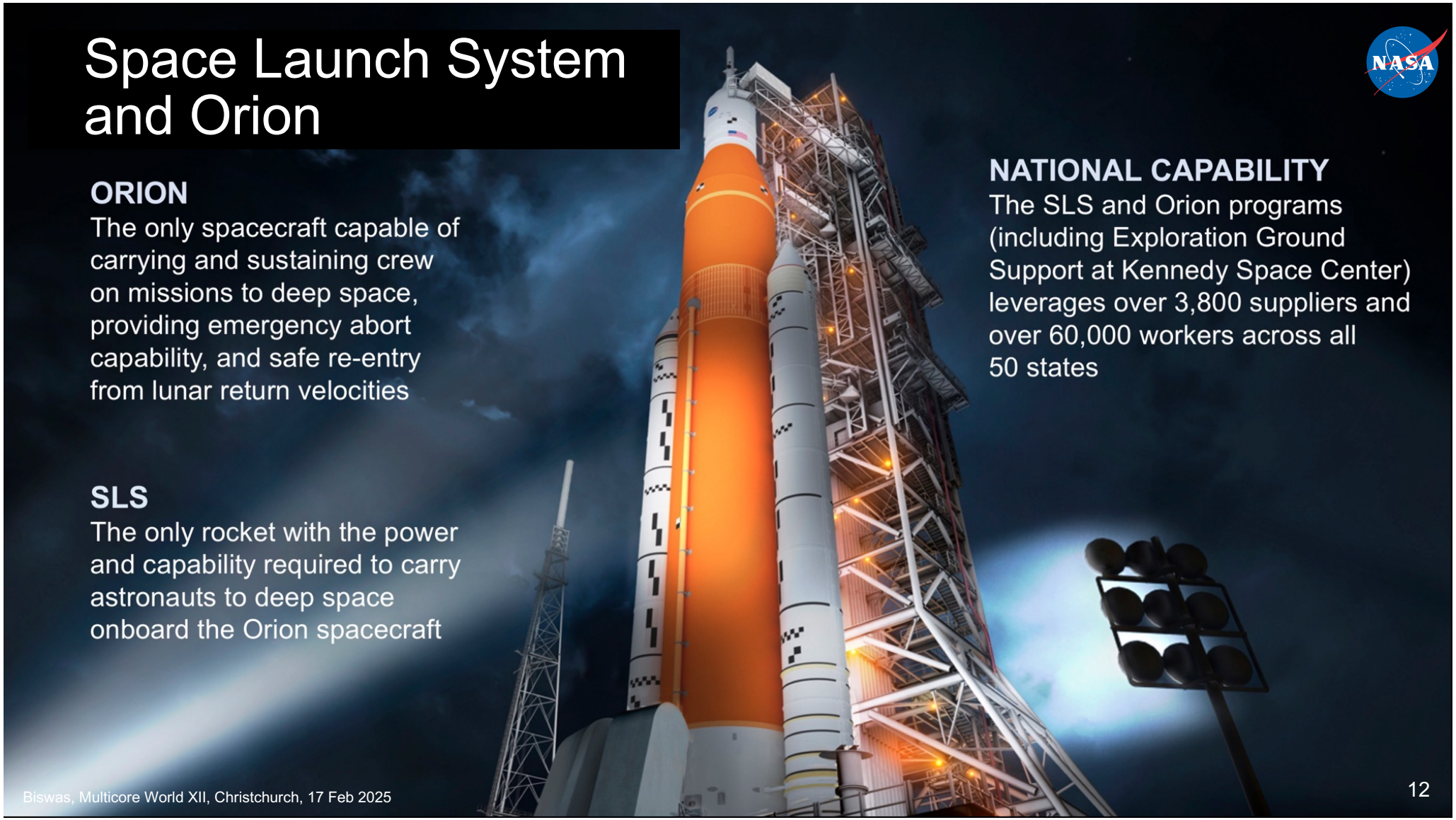
- Twin sister of Apollo & goddess of the Moon (in Greek mythology)
- Astronauts will be where no human has ever been: the Moon's south pole



Next era of space exploration

- A parallel path to success: Government & commercial partners
- NASA Space Launch System (SLS) and Orion programs primarily for crew
- Commercially-provided Power Propulsion Element and pressurized crew module to Gateway
- Human Landing System: Transfer (lander from Gateway to low lunar orbit), Descent (to lunar surface), and Ascent (to Gateway)

Space Launch System and Orion

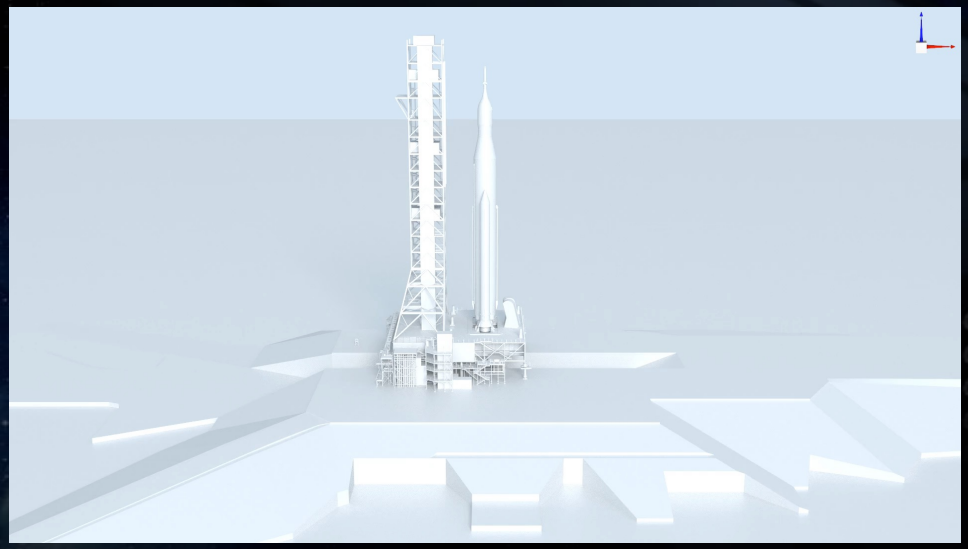


ORION
The only spacecraft capable of carrying and sustaining crew on missions to deep space, providing emergency abort capability, and safe re-entry from lunar return velocities

SLS
The only rocket with the power and capability required to carry astronauts to deep space onboard the Orion spacecraft

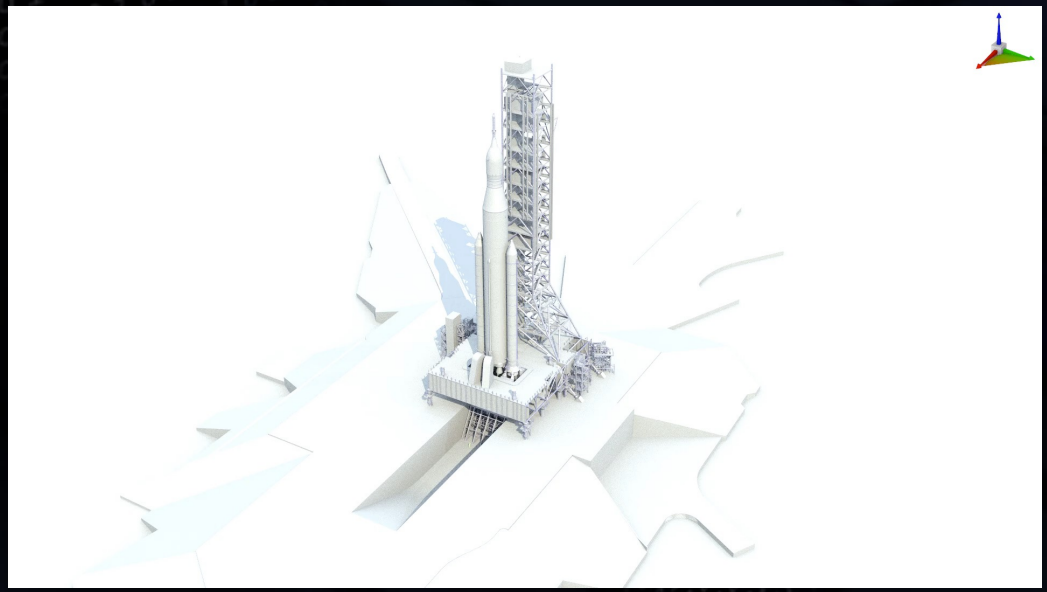
NATIONAL CAPABILITY
The SLS and Orion programs (including Exploration Ground Support at Kennedy Space Center) leverages over 3,800 suppliers and over 60,000 workers across all 50 states

SLS Launch Environment

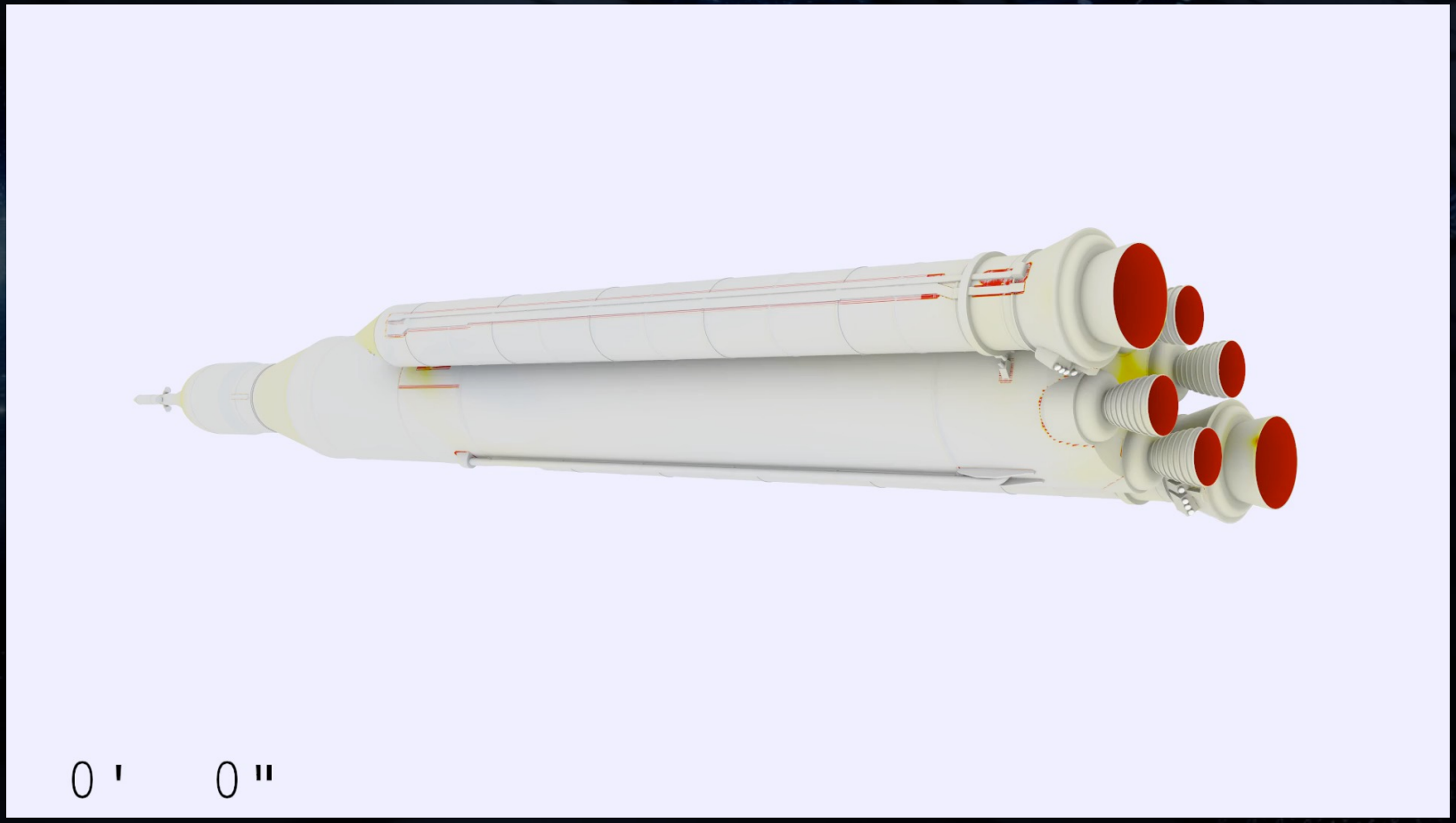


Visualization of launch environment geometry used in LAVA Cartesian simulation

Temperature cutting plane passing through an SRB centerline (green people shown for scale)

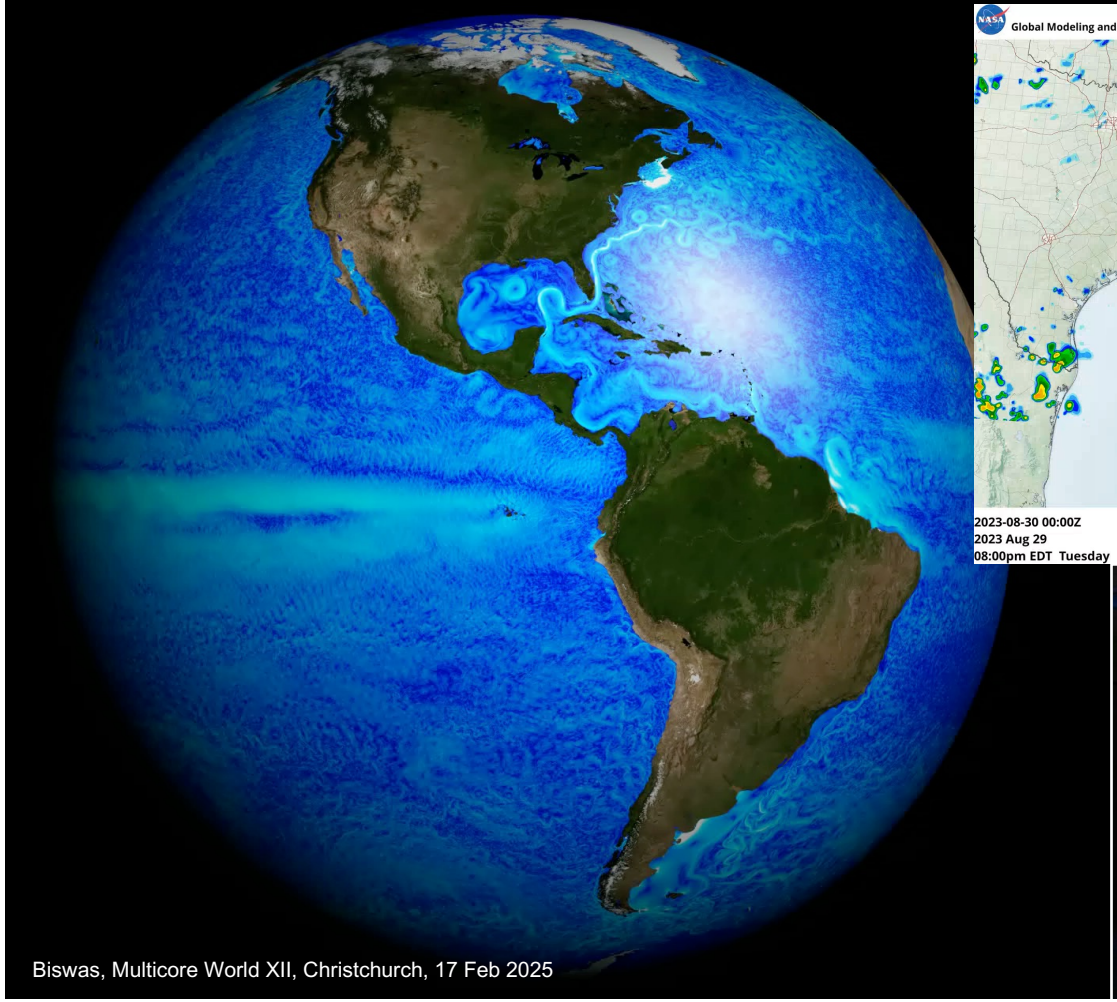


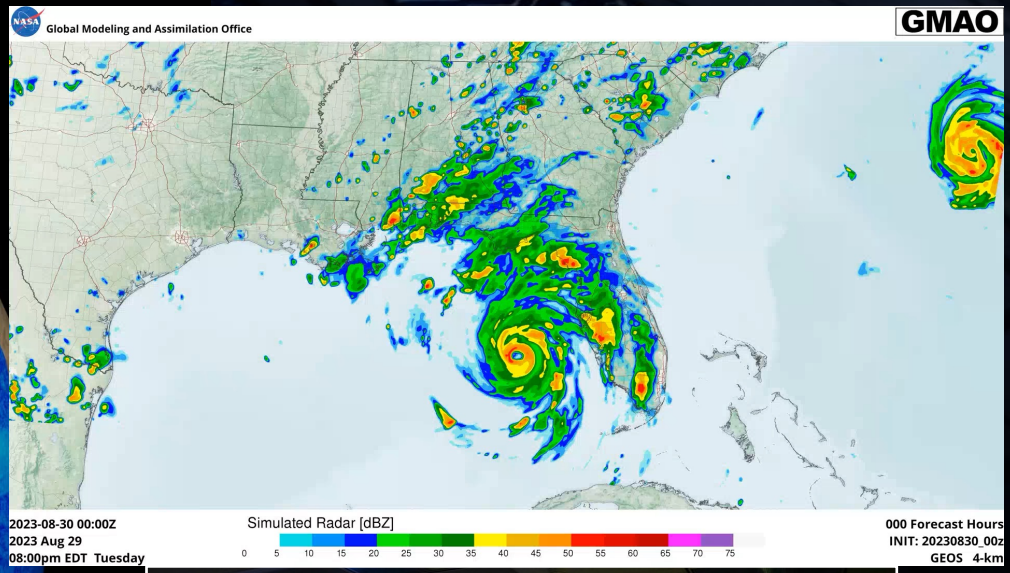
Booster Separation from SLS



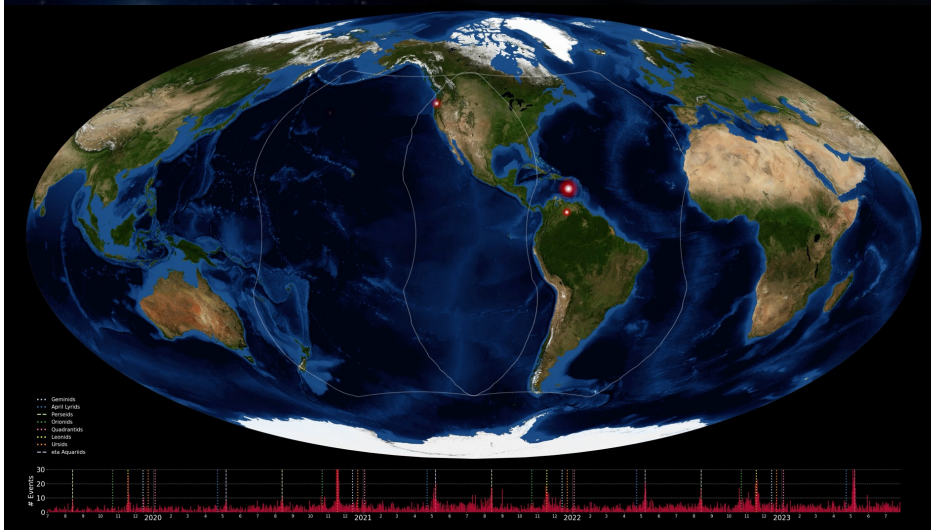
Stage separation at Mach 4 (particles colored by velocity)

Ocean Modeling & Weather Prediction

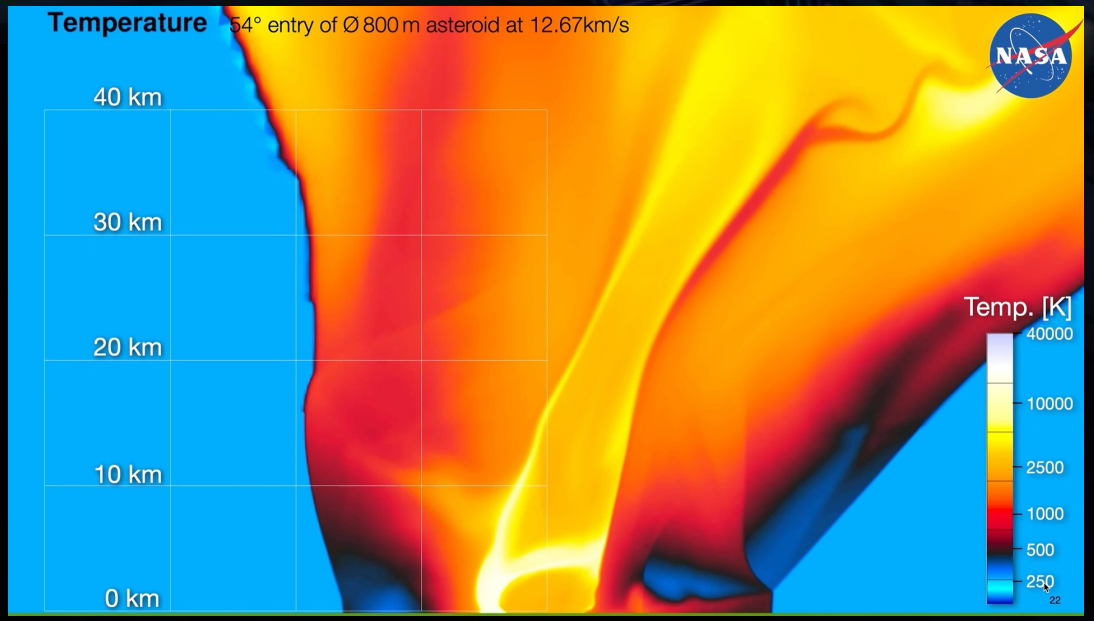




Asteroid Threat Assessment

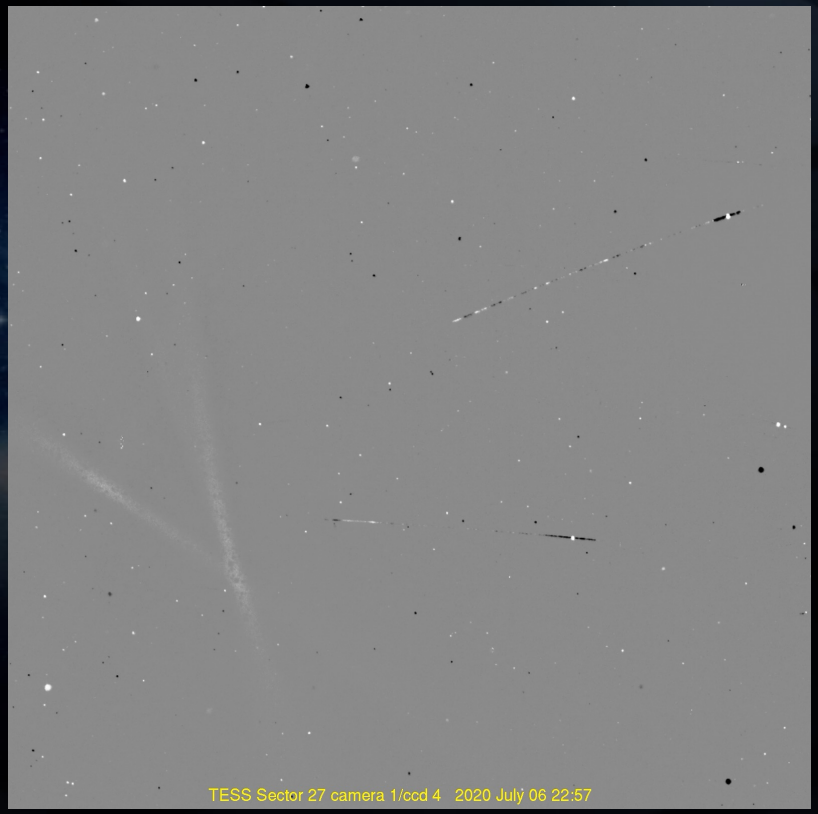


Large exploding meteors (bolides) in Earth's atmosphere detected by NOAA's GOES GLM instruments

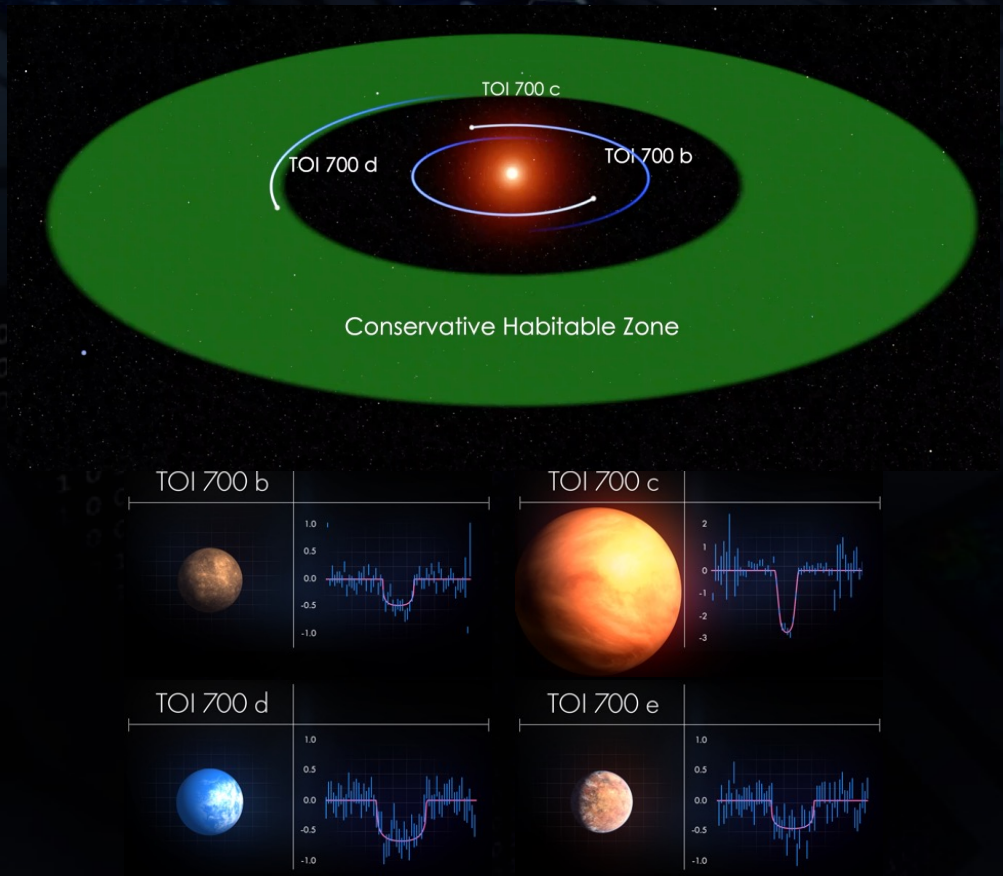


Blast wave propagation and atmospheric response to entry of hypothetical asteroid (800m) at 12.6 km/s – releases 10 gigatons of energy

Transiting Exoplanet Survey Satellite (TESS)

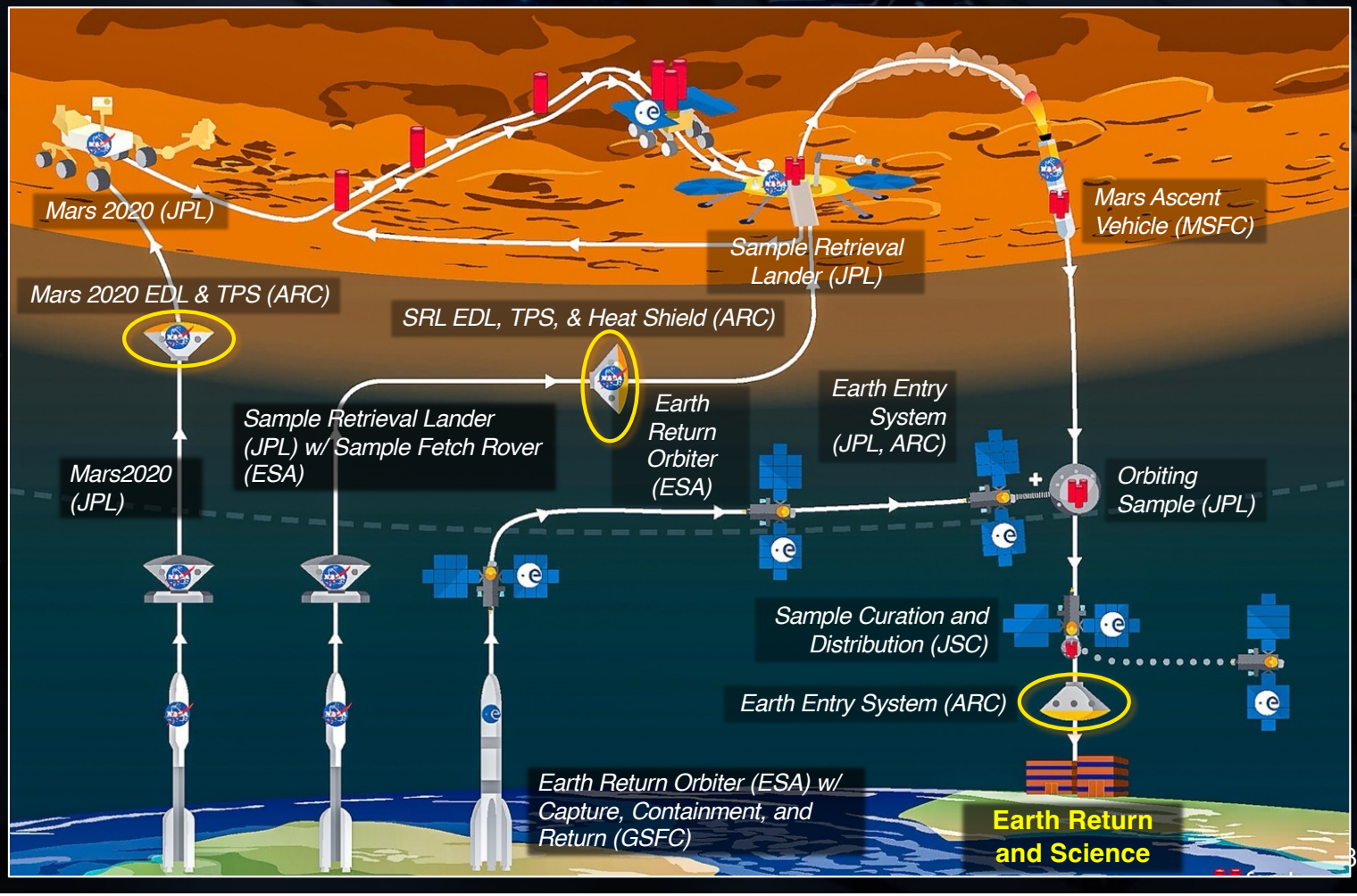


Light curve of an eclipsing binary (lower left), and of a RR Lyrae variable star (upper right)

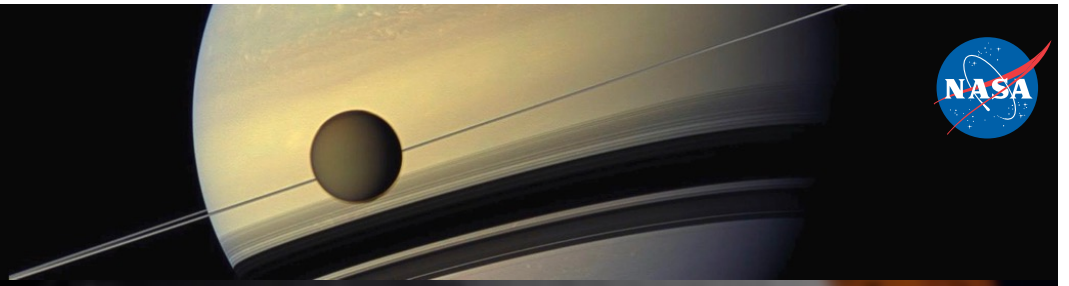


TOI-700, planetary system with two planets in the habitable zone

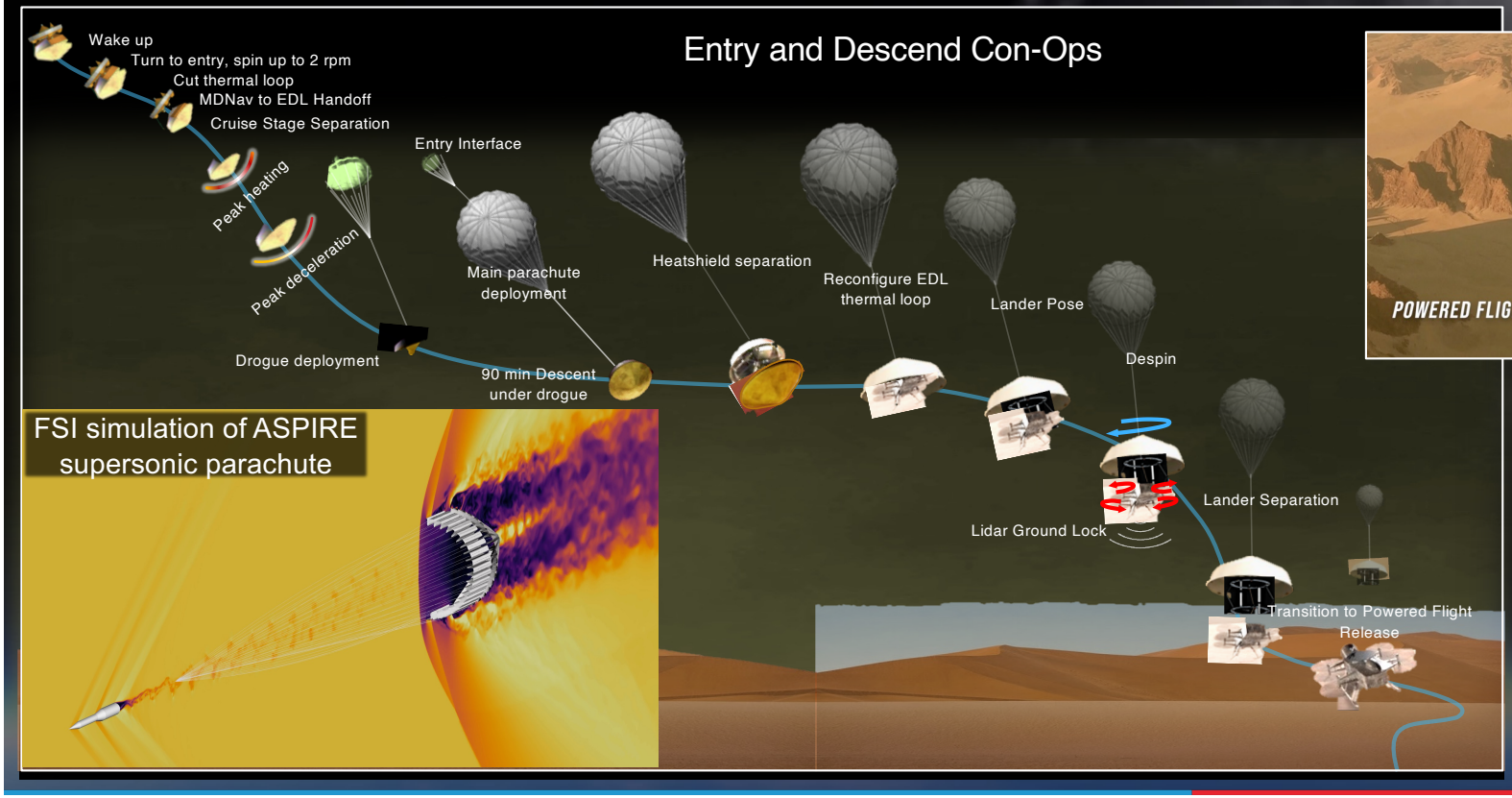
Mars Sample Return

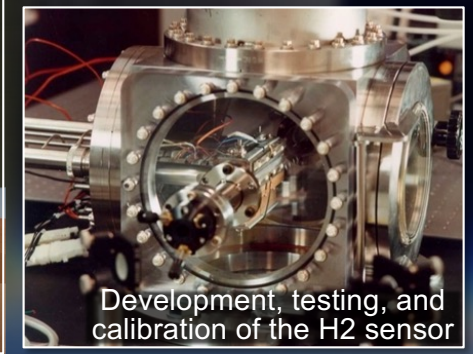


DRAGONFLY



Entry and Descend Con-Ops





NASA Earth Exchange (NEX)

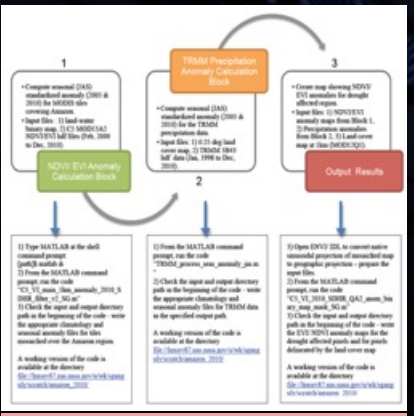
A virtual collaborative environment that brings scientists and researchers together in a knowledge-based social network along with observational data, necessary tools, and computing power to provide transparency and accelerate innovation: **Science-as-a-Service**

VIRTUAL COLLABORATION

Over 650 members

CENTRALIZED DATA REPOSITORY

Over 3.5 PB of observational data



SCALABLE COMPUTING

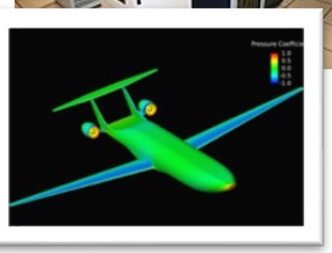
Heterogeneous and remote, secure access

KNOWLEDGE

Workflows, virtual machine images, model codes, and reusable software

Aeronautics

Pleiades
12,000 CPU Nodes
1.7 PFLOPS
3.6 MW
2012



Steady-state simplified wing, forces and moments, 10s of weeklong simulations on 10s of CPU nodes.

Aitken
3,700 CPU Nodes
15.7 PFLOPS
2.4 MW
2024

Unsteady scale resolving analysis of high-lift aircraft (wind–tunnel scale), 10s of weeklong simulations on 100s of CPU nodes.

System A
13,000 CPU Nodes + 9,000 GPU Nodes
411 PFLOPS
20 MW
2026

Unsteady scale-resolving aircraft simulations, including propulsion airframe integration loads and acoustics at flight scale, 100s of single day simulations on 500 GPU nodes.

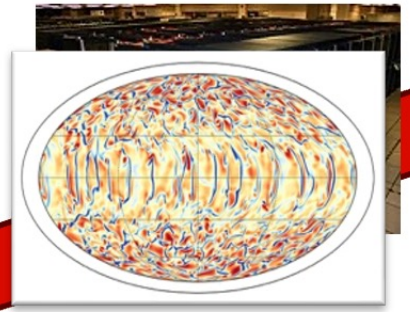
System B
18,000 GPU Nodes
4 EFLOPS
19 MW
2031

Certification by analysis through full-physics aircraft assessment including loads, acoustics, flutter, propulsion, dynamic pitching, 100s of simulations on 1000 GPU.

High-Fidelity Aerodynamics: Scales Resolving Multi-Disciplinary Aircraft Simulations for Certification by Analysis

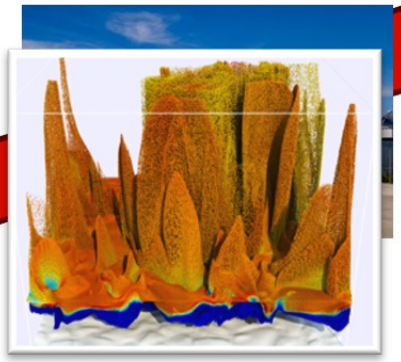
Understanding Our Star

Pleiades
12,000 CPU Nodes
1.7 PFLOPS
3.6 MW
2012



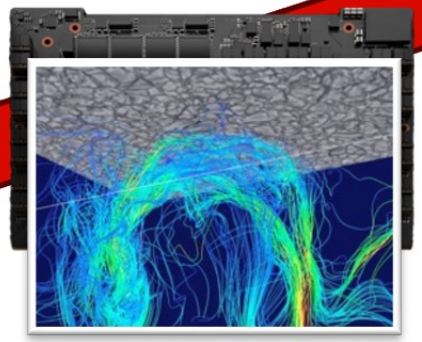
Global modeling of the Sun in the anelastic approximation to study global solar activity
100 nodes from 120 - 360 hours per case

Aitken
3,700 CPU Nodes
15.7 PFLOPS
2.4 MW
2024



3D realistic MHD radiative modeling of the solar convection and corona to investigate the coupling of subsurface dynamics with the solar atmosphere
160-300 nodes for 2,500,000 CPU-hours

System A
13,000 CPU Nodes + 9,000 GPU Nodes
411 PFLOPS
20 MW
2026



Full-scale 3D radiative modeling formation of active regions and associated activity in the solar atmosphere
200-1000 nodes for 5,100,000 CPU hours

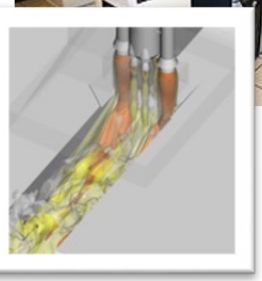
System B
18,000 GPU Nodes
4 EFLOPS
19 MW
2031

Development of multi-scale data-driven assimilation models to predict the evolution of solar activity on global scales and high-energy eruptive activity
200-500 nodes 24 hours, Millions of cases

High-Fidelity Simulations of Solar Activity & Enabling Reliable Space Weather Forecast

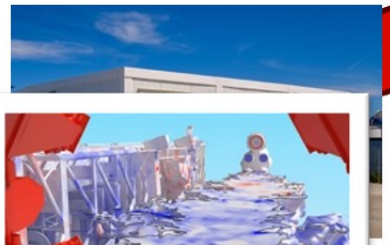
Launch Environment

Pleiades
12,000 CPU Nodes
1.7 PFLOPS
3.6 MW
2012



Single-species, static vehicle, weeklong simulations on 100 CPU nodes

Aitken
3,700 CPU Nodes
15.7 PFLOPS
2.4 MW
2024



Multi-phase, static trajectory points, month long simulations on 100 CPU nodes

System A
13,000 CPU Nodes + 9,000 GPU Nodes
411 PFLOPS
20 MW
2026

Multi-phase, moving vehicle, weeklong simulations on 500 GPU nodes

System B
18,000 GPU Nodes
4 EFLOPS
19 MW
2031

Multi-physics, moving vehicle, Monte-Carlo uncertainty quantification, weeklong simulations on 2000 GPU nodes

Rocket Launch Simulations: Risk Reduction via Moving Vehicle Acoustic Predictions


NASA
*Concept image