FUN3D v14.1 Training
FUN3D Performance at NAS

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(Updated January 2026 to include AMD Turin CPU and NAS GH200 GPU data)

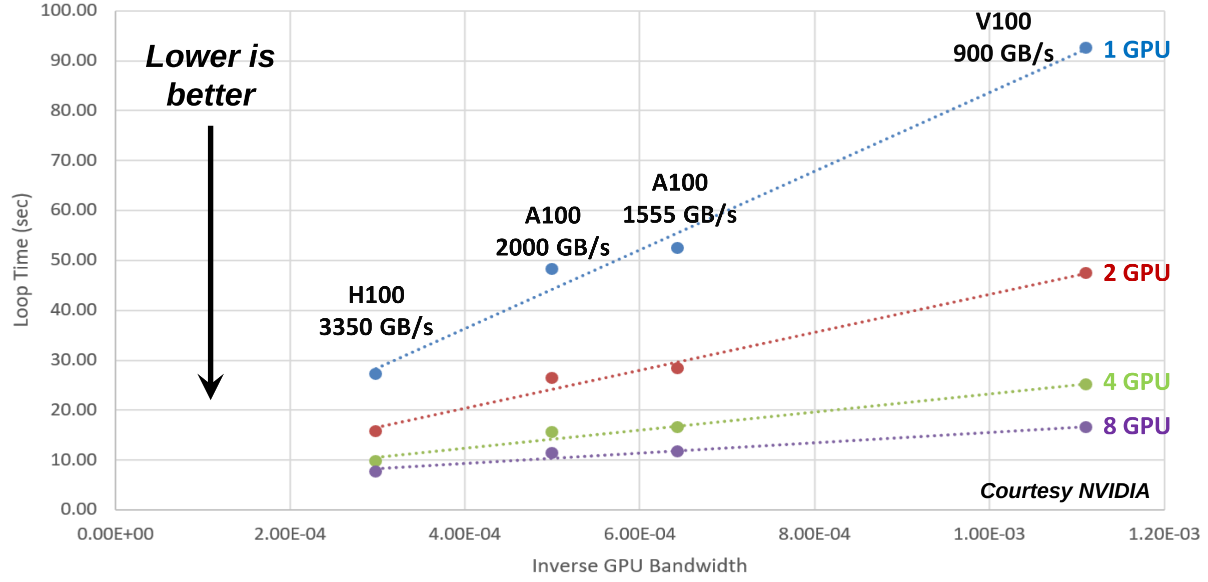
Goal and Scope

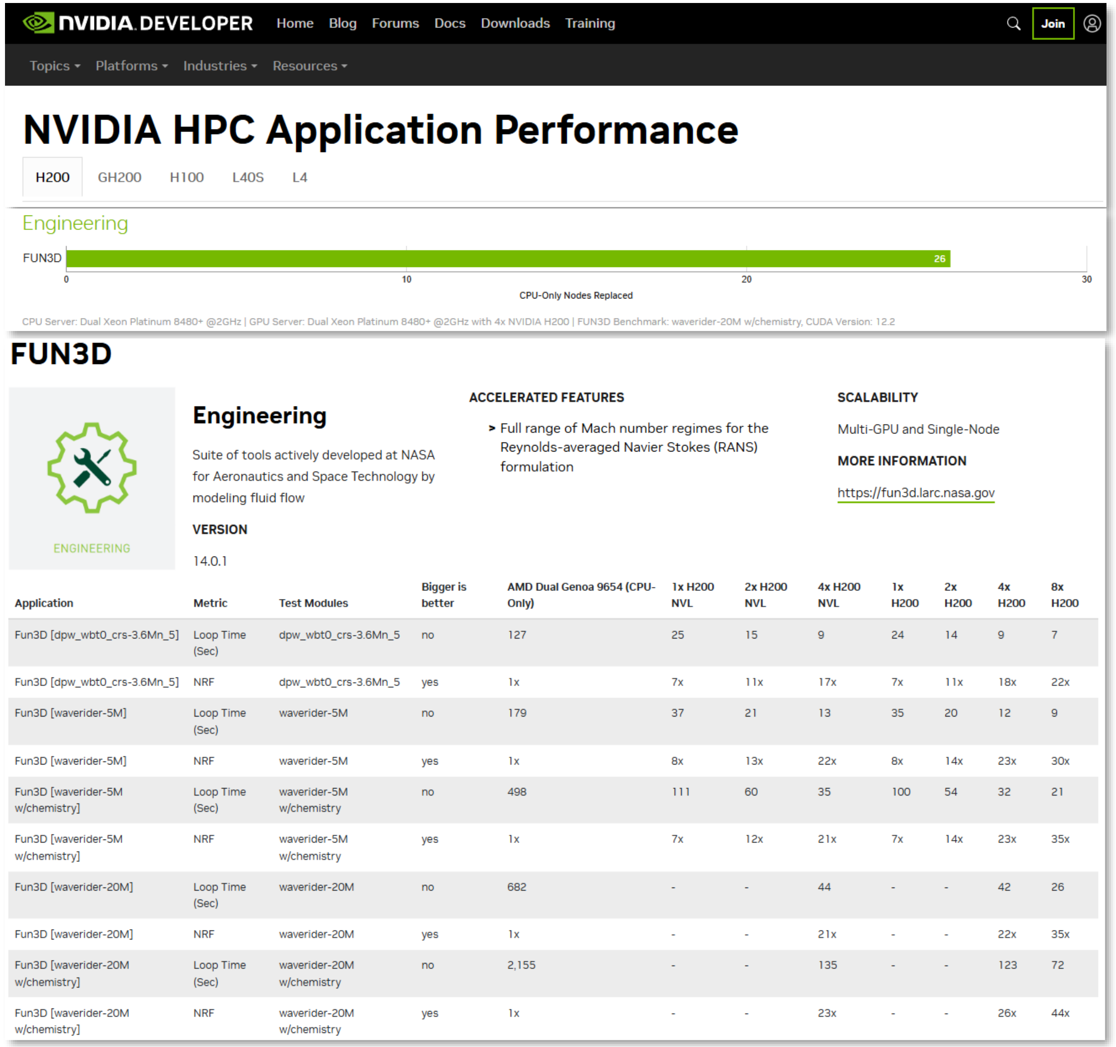
- Goal is to provide device-level performance data for FUN3D finite-volume execution on recent CPU- and GPU-based hardware options available at NAS using simple, yet relevant simulations
- Hopefully such data will be useful in scoping future allocation requests and campaigns on the NAS systems
- What is not covered here:
  - How to run a case
  - Scaling performance
  - What options are / are not available for GPU execution
  - Execution on AMD or Intel GPUs
  - User workflows vary widely in practice; potential impacts are only briefly touched on here
- For such topics, please see the FUN3D User Manual, FUN3D publications, and/or the broad range of training content archived on https://fun3d.larc.nasa.gov , as well as the documentation available on the NAS website
- If questions remain, please reach out to fun3d-support@lists.nasa.gov

Background

FUN3D is memory bound:
In general, performance scales with memory bandwidth

FUN3D Performance on Recent NVIDIA Architectures





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NVIDIA HPC Application Performance

H200 GH200 H100 L40S L4

Engineering

FUN3D 26

0 10 20 30

CPU-Only Nodes Replaced

CPU Server: Dual Xeon Platinum 8480+ @2GHz | GPU Server: Dual Xeon Platinum 8480+ @2GHz with 4x NVIDIA H200 | FUN3D Benchmark: waverider-20M w/chemistry, CUDA Version: 12.2

FUN3D

ENGINEERING

Engineering

Suite of tools actively developed at NASA for Aeronautics and Space Technology by modeling fluid flow

VERSION

14.0.1

ACCELERATED FEATURES

> Full range of Mach number regimes for the Reynolds-averaged Navier Stokes (RANS) formulation

SCALABILITY

Multi-GPU and Single-Node

MORE INFORMATION

https://fun3d.larc.nasa.gov

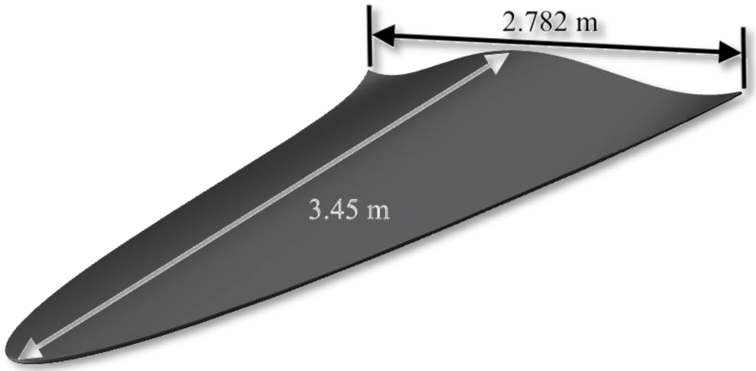
Application	Metric	Test Modules	Bigger is better	AMD Dual Genoa 9654 (CPU-Only)	1x H200 NVL	2x H200 NVL	4x H200 NVL	1x H200	2x H200	4x H200	8x H200
Fun3D [dpw_wbt0_crs-3.6Mn_5]	Loop Time (Sec)	dpw_wbt0_crs-3.6Mn_5	no	127	25	15	9	24	14	9	7
Fun3D [dpw_wbt0_crs-3.6Mn_5]	NRF	dpw_wbt0_crs-3.6Mn_5	yes	1x	7x	11x	17x	7x	11x	18x	22x
Fun3D [waverider-5M]	Loop Time (Sec)	waverider-5M	no	179	37	21	13	35	20	12	9
Fun3D [waverider-5M]	NRF	waverider-5M	yes	1x	8x	13x	22x	8x	14x	23x	30x
Fun3D [waverider-5M w/chemistry]	Loop Time (Sec)	waverider-5M w/chemistry	no	498	111	60	35	100	54	32	21
Fun3D [waverider-5M w/chemistry]	NRF	waverider-5M w/chemistry	yes	1x	7x	12x	21x	7x	14x	23x	35x
Fun3D [waverider-20M]	Loop Time (Sec)	waverider-20M	no	682	-	-	44	-	-	42	26
Fun3D [waverider-20M]	NRF	waverider-20M	yes	1x	-	-	21x	-	-	22x	35x
Fun3D [waverider-20M w/chemistry]	Loop Time (Sec)	waverider-20M w/chemistry	no	2,155	-	-	135	-	-	123	72
Fun3D [waverider-20M w/chemistry]	NRF	waverider-20M w/chemistry	yes	1x	-	-	23x	-	-	26x	44x

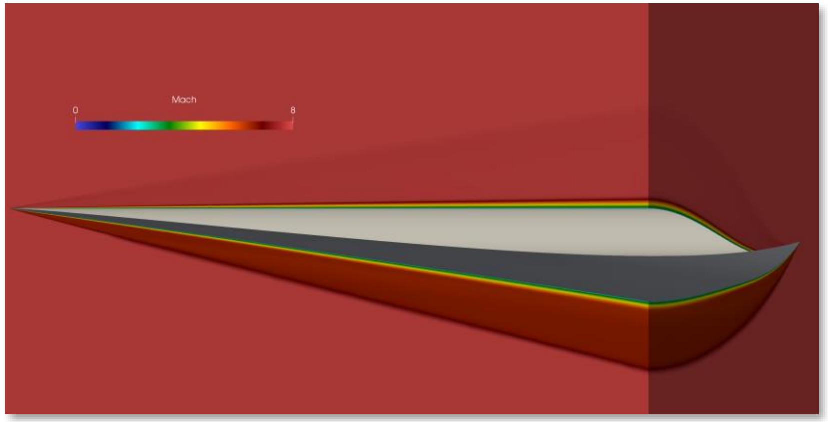
https://developer.nvidia.com/hpc-application-performance

Test Cases

- Tests are performed using the FUN3D v14.1 modules deployed on NAS
- Timings reflect solely the cost of solving the governing equations
- Two test cases are used here, both based on a conceptual hypersonic waverider vehicle
- Freestream conditions are M_∞ = 8.0, T_∞ = 227 K, and Re_L = 9.5 million (30-kilometer altitude)
- Grid consists of 5 million points, 5.3 million prisms, 13.5 million tetrahedra, and 5 thousand pyramids
    - Sized to fit within available memory on the target hardware
- Cases are run using a Reynolds-averaged Navier-Stokes formulation with the single-equation Spalart-Allmaras turbulence model and implicit time integration
- All other inputs taken as FUN3D default values

Case 1 uses a perfect-gas formulation
Case 2 uses a one-temperature, 5-species gas model





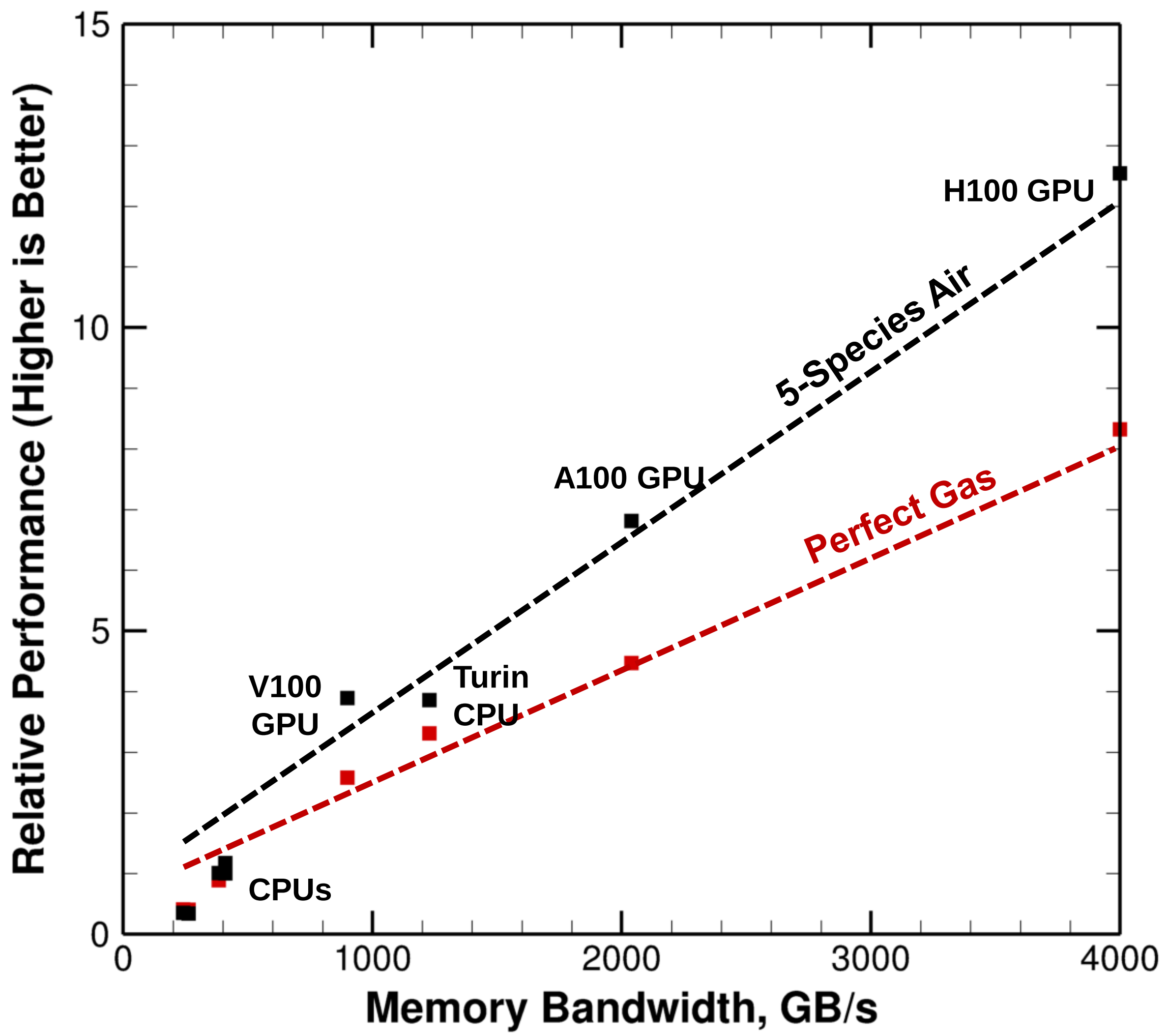
NAS Hardware Specs and Relative FUN3D Performance

	Intel Skylake CPU*	Intel Cascade Lake CPU†	AMD Rome CPU‡	AMD Milan CPU¶	AMD Turin CPU‡‡	NVIDIA V100 GPU§	NVIDIA A100 GPU**	NVIDIA GH200††	
								CPU	GPU
Hardware Details	2 x 20c Xeon 6148	2 x 20c Xeon 6248	2 x 64c 7742	2 x 64c 7763	2 x 128c 9745	32 GB SXM	80 GB SXM	72c Grace	96 GB SXM H100
Peak Memory Bandwidth, GB/s	240	262	410	410	1,228	900	2,039	384	4,000
FUN3D Performance: Perfect Gas	0.41	0.40	1.00	1.14	3.31	2.58	4.47	0.89	8.32
FUN3D Performance: 5-Species Air	0.35	0.34	1.00	1.17	3.86	3.89	6.81	1.01	12.54

- All simulations are performed using a single CPU node (all available cores) or a single GPU
- Performance is normalized by the Rome CPU result and **independently for each gas model**; higher numbers are better

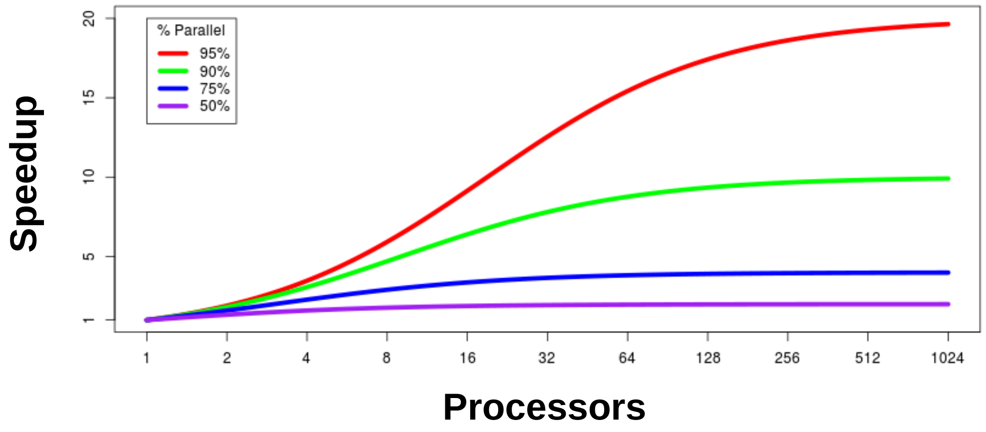
* *https://en.wikichip.org/wiki/intel/xeon_gold/6148*
† *https://en.wikichip.org/wiki/intel/xeon_gold/6248*
‡ *https://www.amd.com/content/dam/amd/en/documents/products/epyc/amd-epyc-7002-series-datasheet.pdf*
¶ *https://www.amd.com/en/products/processors/server/epyc/7003-series/amd-epyc-7763.html*
‡‡ *https://www.amd.com/en/products/processors/server/epyc/9005-series/amd-epyc-9745.html*
§ *https://images.nvidia.com/content/technologies/volta/pdf/tesla-volta-v100-datasheet-letter-fnl-web.pdf*
** *https://www.nvidia.com/content/dam/en-zz/Solutions/Data-Center/a100/pdf/nvidia-a100-datasheet-nvidia-us-2188504-web.pdf*
†† *https://resources.nvidia.com/en-us-grace-cpu/grace-hopper-superchip*

Relative FUN3D Performance on NAS Hardware



GPU Computing and Amdahl's Law

- GPU computing can be game-changing for costly CFD applications, e.g.,
  - Scale-resolving simulations
  - Aeroelastic applications
  - Trajectory analysis / 6-DOF simulations
  - Finite-rate chemistry with complex gas models
- Similar benefits can certainly be realized for engineering-class applications (e.g., steady-state RANS using perfect gas), but one should be aware of some implications related to Amdahl's Law



Amdahl's Law at the Solver and Workflow Levels

Solver Level

- All steps needed to solve the governing equations are performed on the GPU
- However, some auxiliary operations take place on the CPU; some are optional but some may not be
  - Some of these kernels do not map well to a GPU, while the team has simply lacked bandwidth to address others
  - Long-duration simulations easily amortize many of these operations
  - Engineering-class simulations that run in minutes call for potential mitigation strategies outlined in the User Manual
- We are working hard on new approaches and paradigms here – hopefully to appear in future releases

Workflow Level

- Most engineering workflows are far more complicated than simply solving Navier-Stokes on the latest gold shiny hardware, e.g.,
  - Operations / applications / motifs that do not scale or perhaps do not map to certain architectures
  - COTS applications and components
  - File manipulations and file system interactions
  - CAD applications, mesh generation / adaptation
  - Distributed / remote computing
  - Multidisciplinary / multiphysics concerns
- Tough to offer general solutions here, but always happy to chat

- **Get a small allocation and run some tests with your actual workflow or a close surrogate**
- **Please reach out to us – your real-world challenges and feedback are extremely valuable**

Summary

- Performance and scaling will vary with specific user workflows, but the general trends shown here should hold
- Explore some representative tests ahead of time if possible
- See User Manual, publications, and prior tutorials regarding performance and suggestions when computing in GPU environments
- Please feel free to contact us at fun3d-support@lists.nasa.gov to discuss specific workflows or questions