# FUN3D v13.1 Training

# Session 2: Welcome and Overview

Eric Nielsen



## FUN3D Training Workshop

**July 30, 2017**

| | |
|---|---|
| Session 1: Introductions | 8:00-8:15 |
| Session 2 Welcome and Overview | 8:15-8:45 |
| Session 3: Compilation and Installation | 8:45-9:00 |
| Session 4: Gridding, Solution, and Visualization Basics | 9:00-10:30 |
| BREAK | 10:30-10:45 |
| Session 5: Adjoint-Based Design for Steady Flows | 10:45-12:00 |

# Administrative Details

- Need to stay on schedule, but please do not hesitate to ask questions
- In-room wireless access:
  - Network: Password:
- Please submit your evaluation form at the end of the workshop
  - Very interested in your feedback, good or bad!



# All Material Available Online

- For the v13.1 material presented here:
  - Slides online in PDF format
  - To obtain FUN3D, see website for link to NASA Software Catalog
- A FUN3D v13.1 manual is available as NASA/TM-2017-219580 on the website
  - You should also receive a copy of this with the source code distribution
  - Additional material will continue to be added with new releases
  - Your feedback/suggestions are extremely helpful
- Extensive material from prior training workshops is available on the website
  - Slides in PDF
  - Pro-shot streaming video
  - Demo content can be downloaded as a tarball
- We hope to eventually add an extensive tutorials document

# The FUN3D Development Team

fun3d-developers@lists.nasa.gov

- Consists of ~15-20 researchers across several branches at Langley
  - Computational AeroSciences Branch
  - Aerothermodynamics Branch
- Some people are full-time FUN3D, others part-time
  - Spectrum runs from full-time development to full-time applications
- Also external groups such as Georgia Tech, National Institute of Aerospace (NIA)
- Open to other interested parties joining us
  - Remote, real-time, read/write access to FUN3D repository is available



# The FUN3D Support Team

fun3d-support@lists.nasa.gov

***"Who sees my questions to the support alias?"***

- Consists of 16 members of the development team
- All are NASA civil servants
  - Proprietary/sensitive data can be shared/discussed: all are bound by Trade Secrets Act
- Members: Kyle Anderson, Bob Biedron, Jan-Renee Carlson, Cameron Druyor, Peter Gnoffo, Dana Hammond, Bill Jones, Bil Kleb, Beth Lee-Rausch, Steve Massey, Eric Nielsen, Matt O'Connell, Mike Park, Kyle Thompson, Aaron Walden, Jeff White

Myth: Our job is to develop a production-level tool and support users.

Reality: ***None*** of us are funded at ***any*** level to support users, maintain documentation, keep up a website, run training workshops, etc. The team is funded solely to perform their individual research efforts.

# The FUN3D User Community

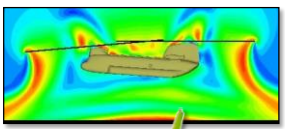
fun3d-users@lists.nasa.gov

- FUN3D widely used within NASA for projects across the speed range
  - Both engineering and research applications
  - Users routinely running on several thousand cores
- Distributed to hundreds of external organizations across academia, industry, DoD, and OGAs
  - Average about 150 distributions / year
  - Wide range of uses including aerospace, automotive, HPC, wind energy, etc.
  - Wide range of hardware being used
  - From RC enthusiasts on single workstation to groups generating matrices of hundreds of solutions on thousands of HPC nodes

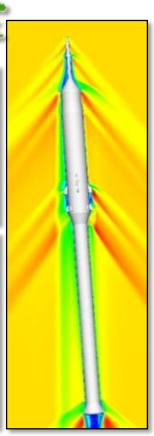


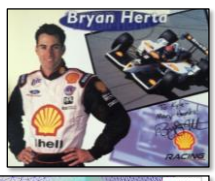
# FUN3D Core Capabilities

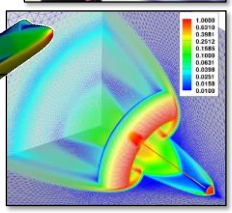
- Established as a research code in late 1980s; now supports numerous internal and external efforts across the speed range
- Solves 2D/3D steady and unsteady Euler and RANS equations on node-based mixed element grids for compressible and incompressible flows
- General dynamic mesh capability: any combination of rigid / overset / morphing grids, including 6-DOF effects
- Aeroelastic modeling using mode shapes, full FEM, CC, etc.
- Constrained / multipoint adjoint-based design and mesh adaptation
- Distributed development team using agile/extreme software practices including 24/7 regression, performance testing
- Capabilities fully integrated, online documentation, training videos, tutorials



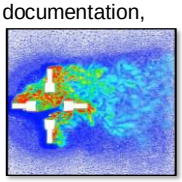
*US Army*

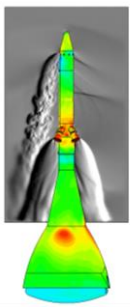


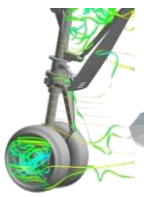


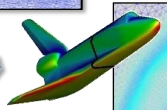



*Georgia Tech*





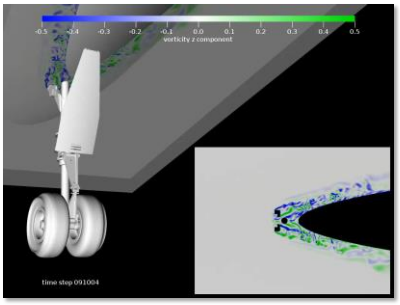


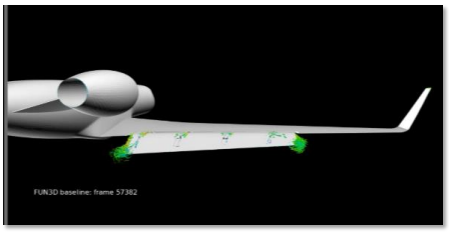


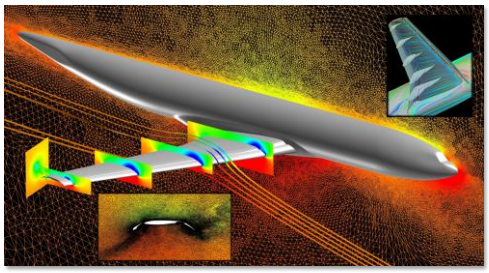
# Some Recent NASA Applications

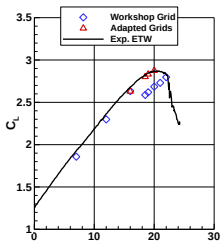
***Airframe Noise***

***Courtesy NASA/Gulfstream Partnership on Airframe Noise Research***






***Adjoint-Based Adaptation for High-Lift***

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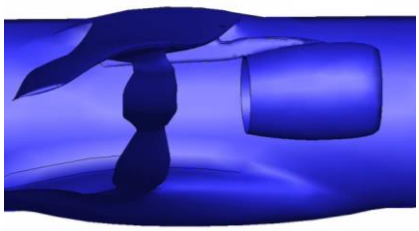
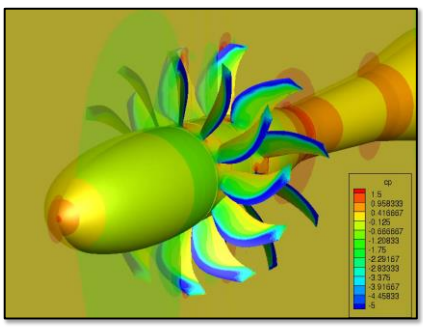
# Some Recent NASA Applications

***Courtesy Bob Bartels***



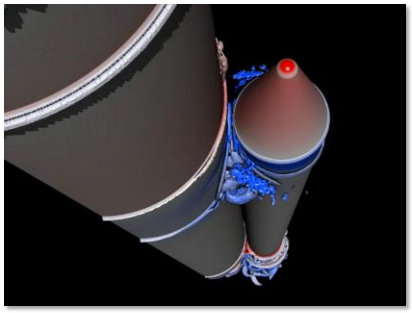
***Open-Rotor Concepts***




***Aeroelastic Analysis of the Boeing SUGAR Truss-Braced Wing Concept***

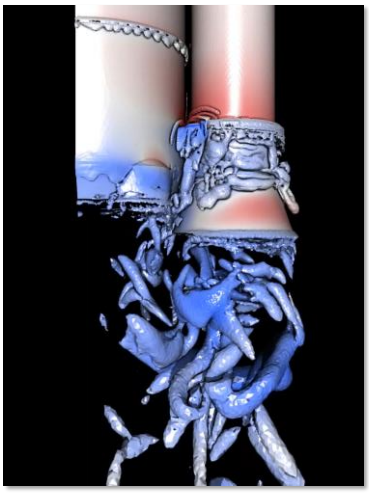
***Courtesy Bill Jones***

# Some Recent NASA Applications



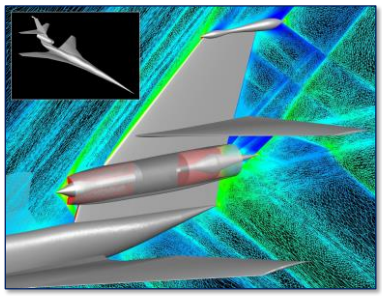
***Transonic Buffet Characterization for Space Launch System***

***Courtesy Greg Brauckmann, Steve Alter, Bil Kleb***

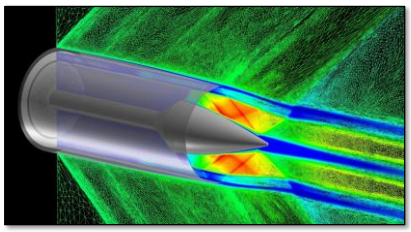


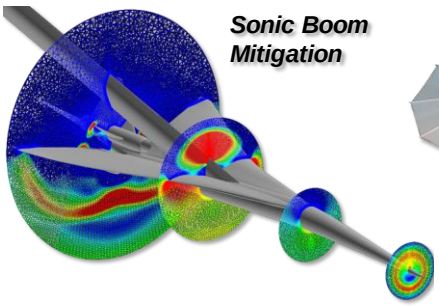


# Some Recent NASA Applications



***Courtesy Chris Heath***



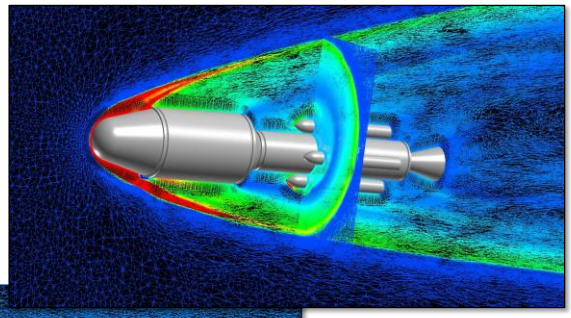


***Sonic Boom Mitigation***

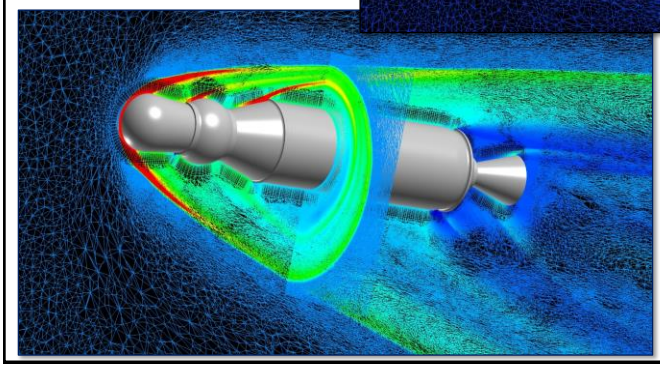
***Mars InSight Lander***

# Some Recent NASA Applications

***Mars Ascent Vehicle for Sample Return***

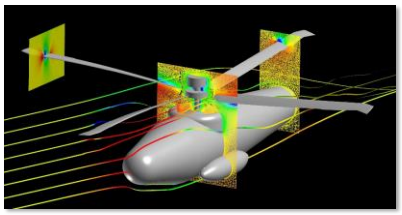


*Courtesy Ashley Korzun*



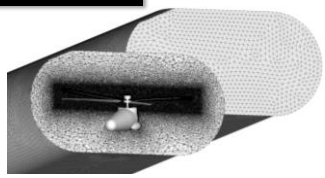
# Some Recent NASA Applications

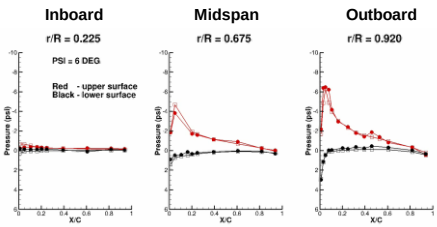
## Validation for Full Scale UH60A



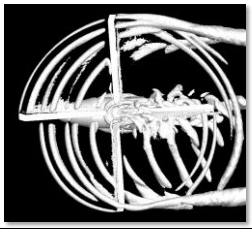
*Courtesy Beth Lee-Rausch, Bob Biedron*

- Structural loads
- Sectional airloads/pressures
- Balance loads
- Control settings
- Blade root motions
- Elastic blade deflections



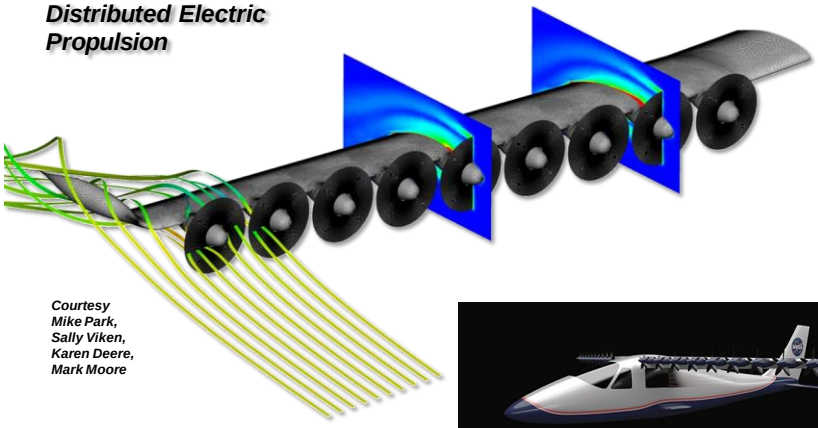



Blade Pressures at High Advance Ratio



# Some Recent NASA Applications

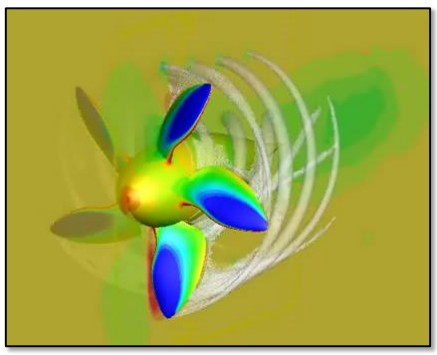
***Distributed Electric Propulsion***



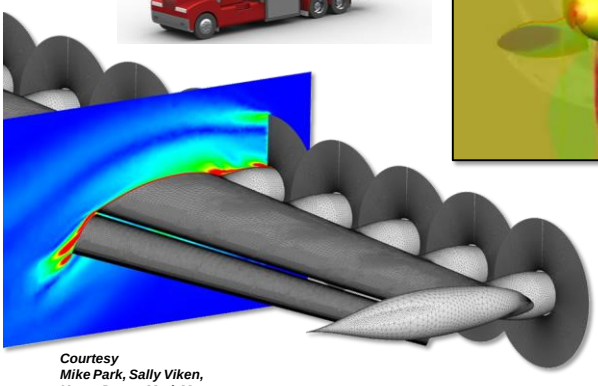
*Courtesy Mike Park, Sally Viken, Karen Deere, Mark Moore*



# Some Recent NASA Applications



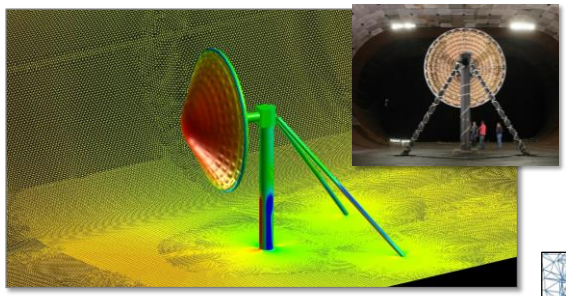
*Courtesy Bill Jones*



***Distributed Electric Propulsion***

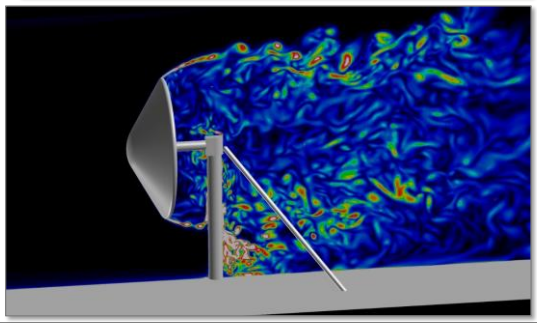
*Courtesy Mike Park, Sally Viken, Karen Deere, Mark Moore*

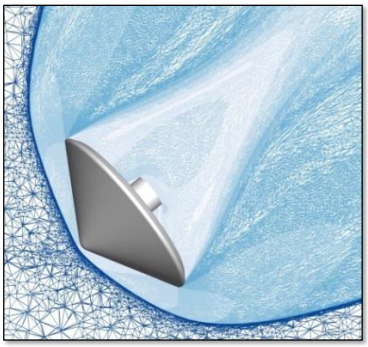
# Some Recent NASA Applications



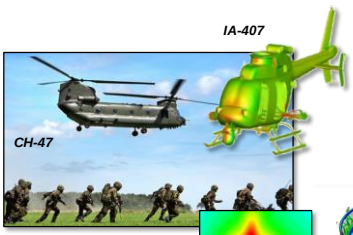
***Aeroelastic Analysis of HIADs: Hypersonic Inflatable Aerodynamic Decelerators***

*Courtesy Beth Lee-Rausch, Bob Biedron, and Bil Kleb*



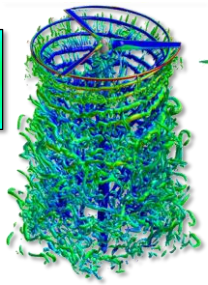


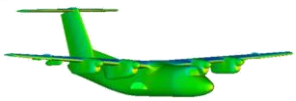
# At the Department of Defense

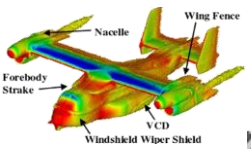


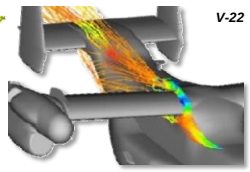

**AMRDEC at Redstone Arsenal**

- **Troop safety:** airworthiness qualification
- **Dramatic cost savings:** fewer tunnel & flight tests
- Intense demand for timely results on massive computing systems
- Decade of use in direct support of the US warfighter








- **NAVAIR at Patuxent River**
- **Air Force Research Laboratory**
- **HPCMP CREATE-AV**

# Across the Aerospace Industry

SPACEX

*First private company to achieve orbit and dock with the International Space Station*

- FUN3D used for extensive analysis of Falcon 1 and Falcon 9 rockets, Dragon spacecraft
- Team consults frequently and provides new features and capabilities as requested

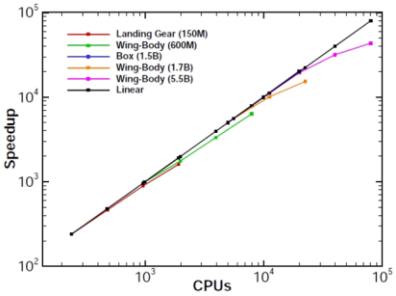
*"The FUN3D software suite and development team have enabled SpaceX to rapidly design, build, and successfully fly a new generation of rockets and spacecraft."*

*- Justin Richeson*
*Manager, SpaceX Aerodynamics*

# FUN3D and High-Performance Computing

***FUN3D is used on a broad range of HPC installations around the country***


OLCF

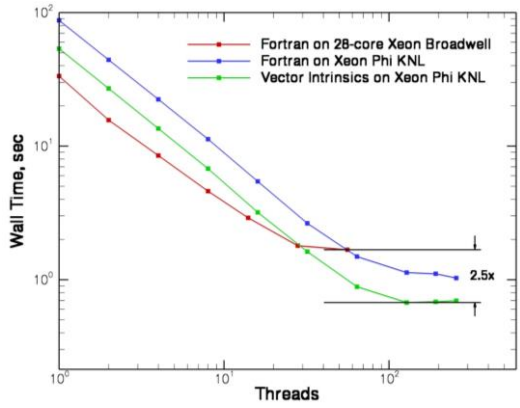





***Scaled to 80,000 cores on DoE's Cray XK7 'Titan' using grids containing billions of elements***

***Awarded the Gordon Bell Prize in a past collaboration with Argonne National Lab***

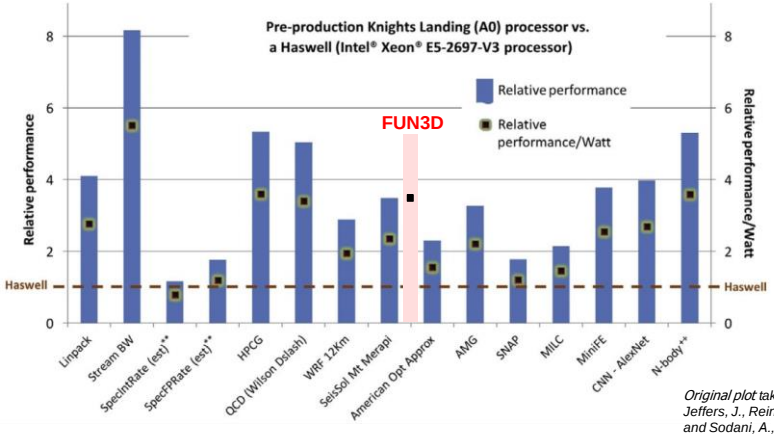
# FUN3D Solver on Intel Xeon Phi




- "Works out of the box" paradigm for KNL is encouraging but dangerous: tempting to declare success before achieving its full potential
- Vector intrinsics on Xeon Phi Knights Landing beat conventional Fortran on 28-core Xeon Broadwell by 2.5x
- Intrinsics attractive for performance (including Skylake and beyond), but effort/portability must be considered



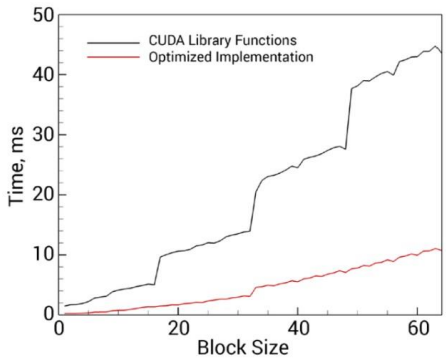
# FUN3D Solver on Intel Xeon Phi




*Original plot taken from Jeffers, J., Reinders, J., and Sodani, A., "Intel Xeon Phi High Performance Programming, Knights Landing Edition," 2016.*

- Using the more common single-socket Haswell benchmark, Knights Landing is 5.4x faster and 3.6x more power-efficient
- Compares well with other early apps

# FUN3D Solver on NVIDIA GPUs




OLD DOMINION UNIVERSITY

NVIDIA

- FUN3D implicit solver also implemented for GPUs using OpenACC, CUDA, and PTX
- Up to 7x improvement over existing CUDA libraries for range of block sizes
- NVIDIA Pascal P100 shows 3.9x speedup over 28-core Xeon Broadwell



# Some Final Notes

- The material that will be shown here represents the current recommended best practices for the perfect gas option in FUN3D
- Many topics omitted from what is normally a two-day course:
  - Boundary conditions, turbulence models, high-speed simulations, geometry parameterization, error estimation and mesh adaptation, time-dependent flows, dynamic and overset grid simulations, adjoints for unsteady flows, aeroelastic simulations, rotorcraft simulations, general-gas simulations
- There are always many research and development efforts taking place within the code that are not described here
- If you do not see something, please ask about it