RotorGen: A Simplified Structured Grid Generation Program for High-Fidelity Rotor CFD Simulation

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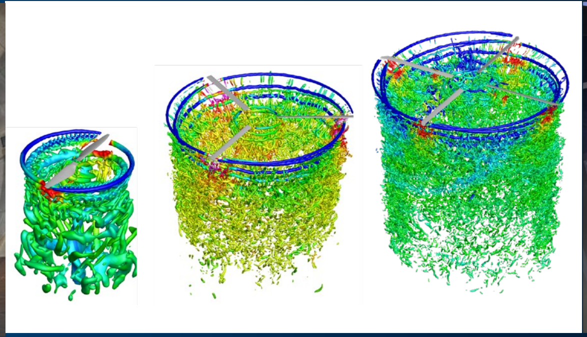
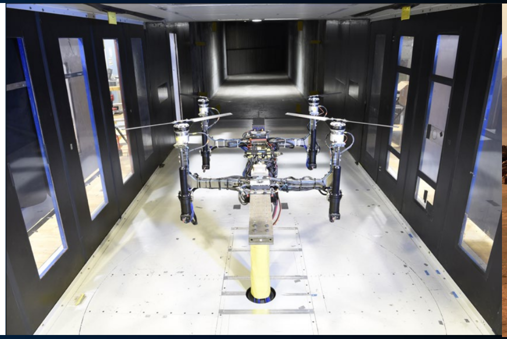




Aeromechanics Branch - NASA Ames Research Center

Overview

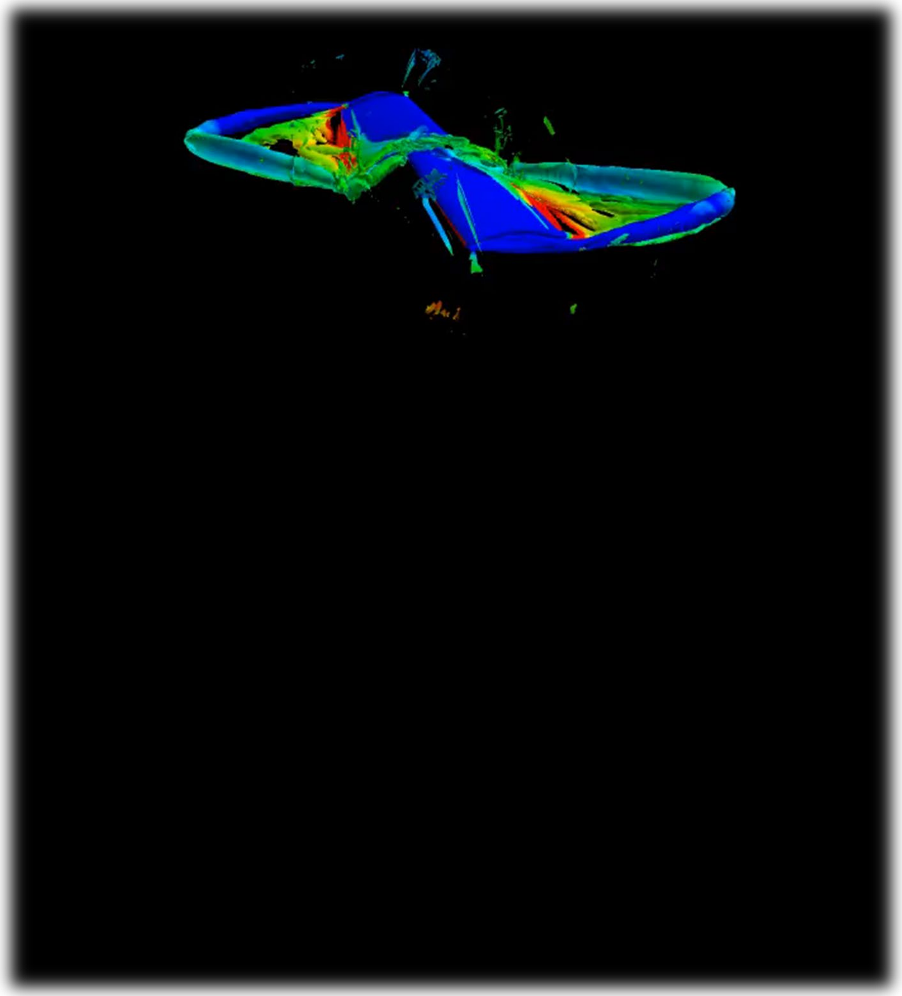
- Motivation
- Overview of RotorGen
- Preliminary Validation Work
- Concluding Remarks

Challenges for Rotorcraft-based CFD Simulation in Conceptual Design

- **There exists challenges in leveraging CFD solutions of rotors in early-stage conceptual design.**
  - Limited usage of CAD rotor representations
  - Coupling to structural and trim solvers
  - Rapidly evolving design space

- **Scriptable grid generation programs exist to complete parametrized CFD studies.**
  - These scripts require significant user expertise to generate

- **There is a need for a high-level, simplified tool for parsing conceptual design-level rotor definitions and rapidly generating high-fidelity CFD cases.**



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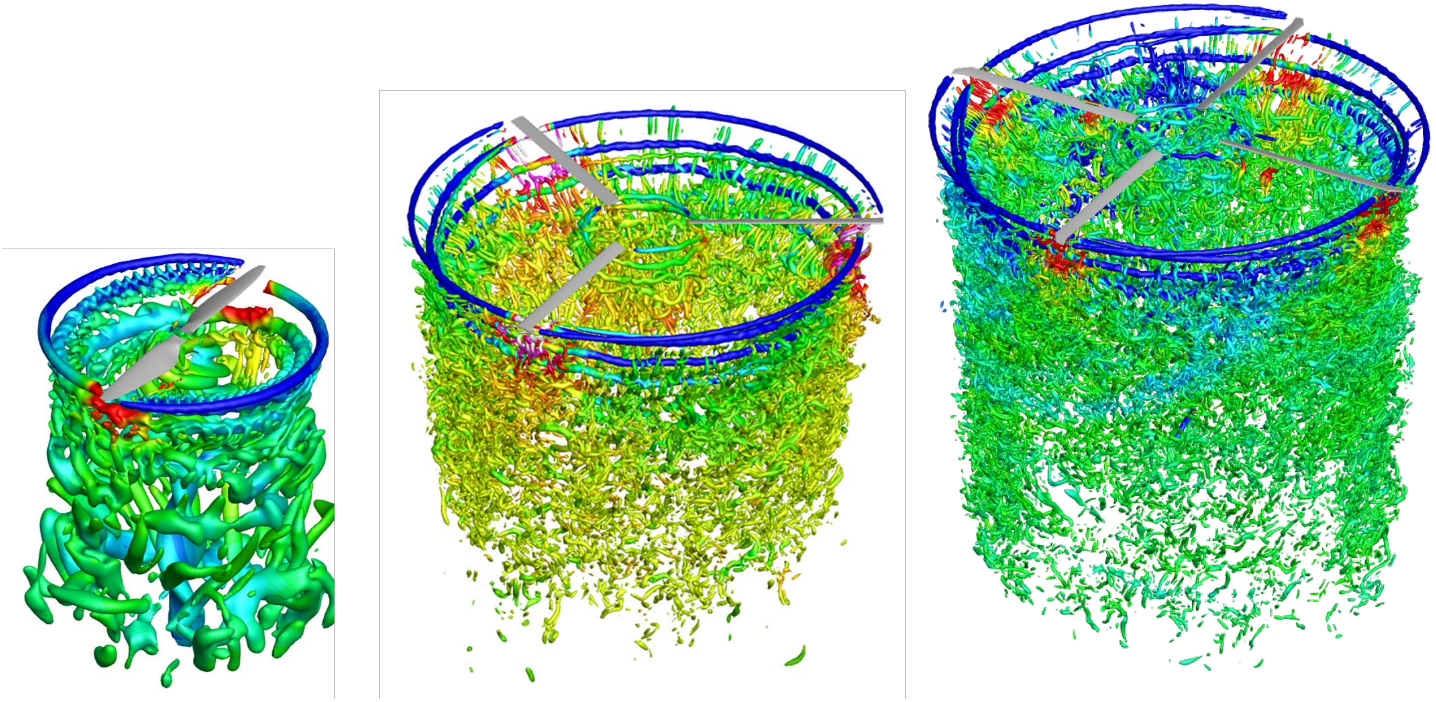
Objectives of RotorGen

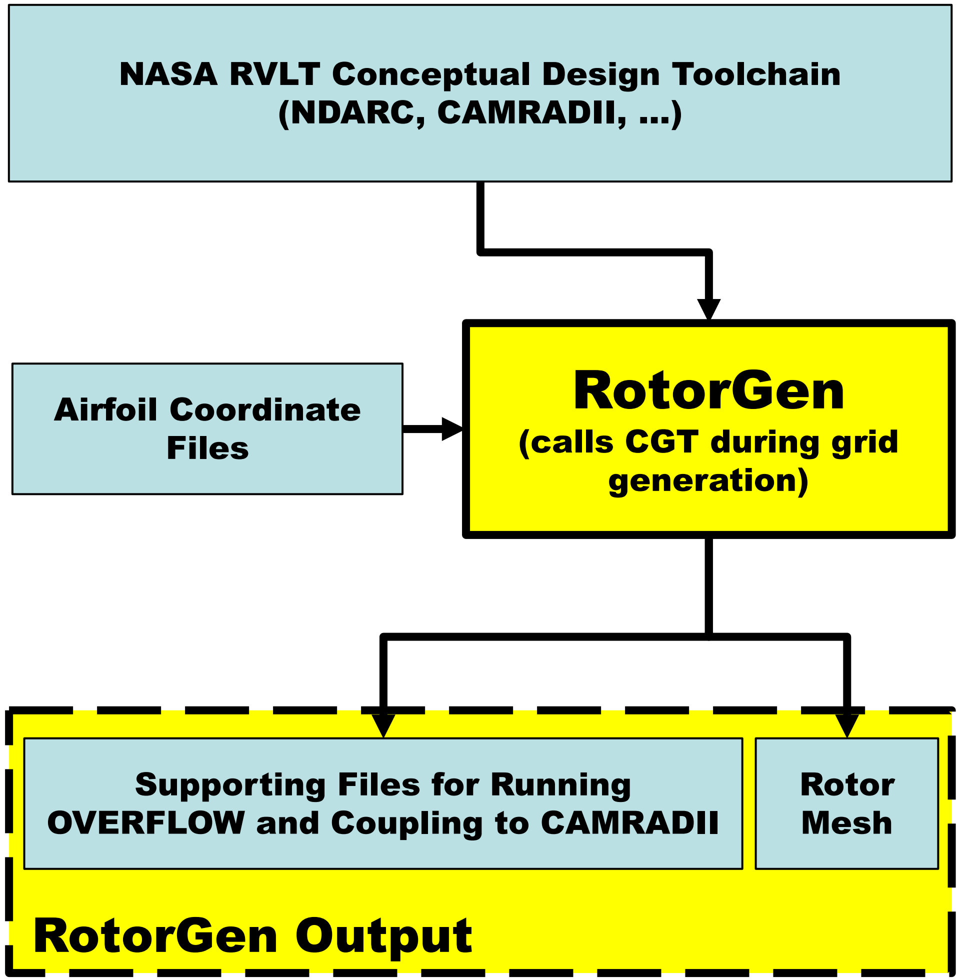
- **The objective of RotorGen is to automatically generate OVERFLOW CFD cases based on conceptual design-level rotor definitions.**

- **In pursuit of this objective, RotorGen promotes the use of high-fidelity solutions among a broader range of rotorcraft-based conceptual design groups.**



High Level Workflow with RotorGen

- **The NASA RVLT Conceptual Design Toolchain is utilized to identify a limited number of interesting cases.**
- **Conceptual design-level definitions for rotor geometric and operating conditions are entered into a single RotorGen input file.**
- **Chimera Grid Tools (CGT) generates multiple overset volume grids to model the rotor.**
- **Time to submit CFD cases reduced from several *days* to a few *seconds*.**
  - Reduce required expertise to run simulation



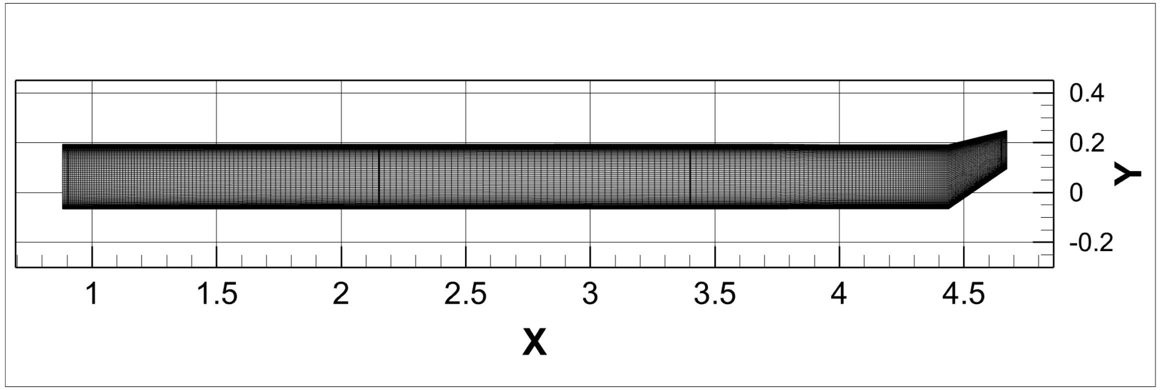
Defining the Blade Planform

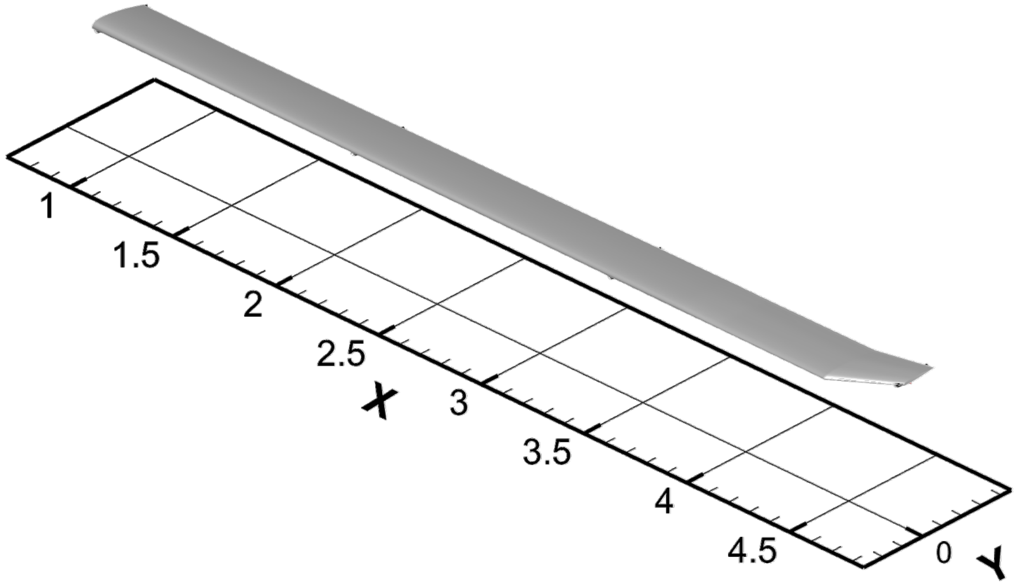
- **Blade planform definitions are provided by the user, detailing geometry.**
  - Definitions define blade spanwise chord, twist, sweep, droop, …
  - Defines blade ¼ chord line

- **Users provide a specific set of airfoil profiles.**

- **User is further allowed detailed control of spanwise mesh refinement.**
  - Varying refinement at user-specified radial stations

Blade Planform



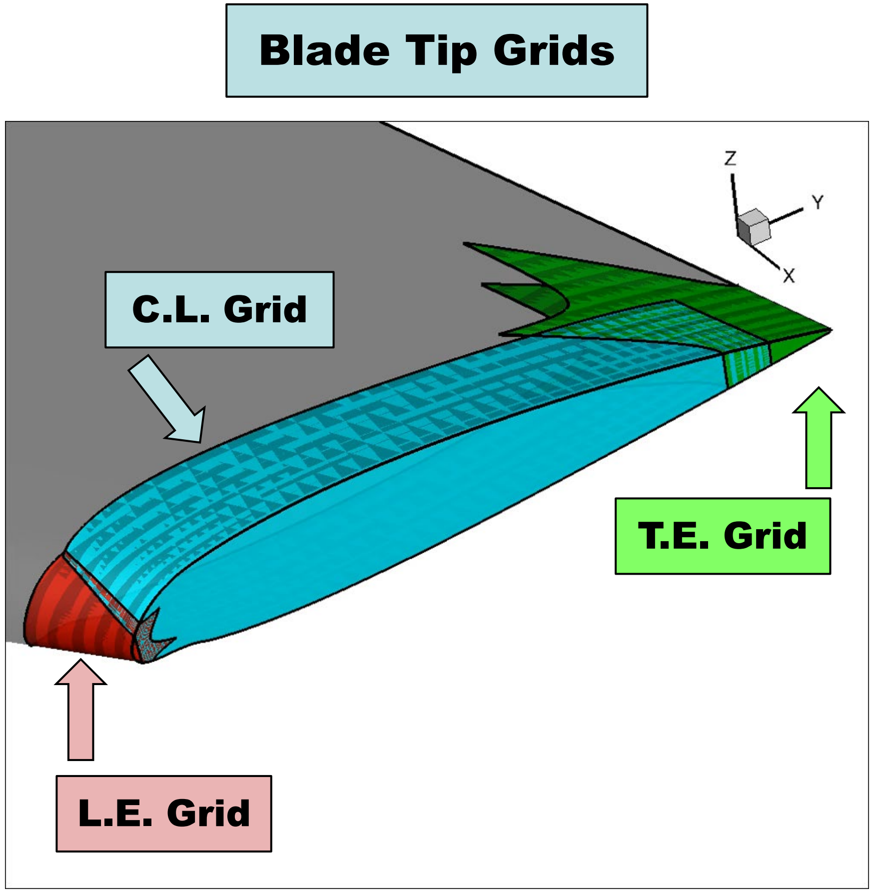


Defining the Blade Tip/Root Cap

- **Tip cap, overset grid generation remains a notoriously rigorous task.**
  - Often a significant source of time spent in grid generation, particularly among non-expert users

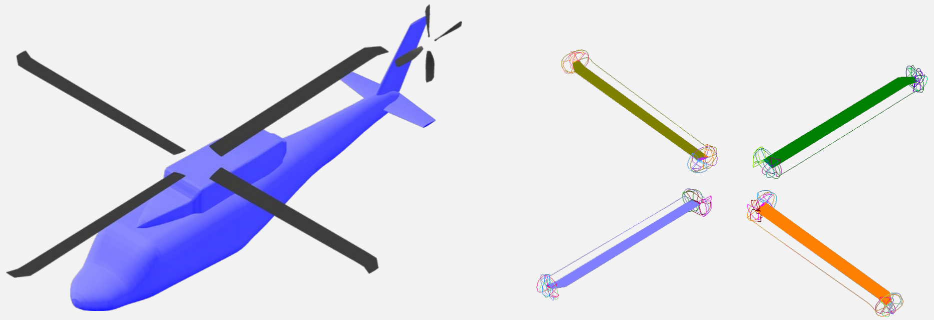
- **To maximize the robustness of cap grid generation, three overset grids are used.**
  - Leading Edge (L.E.) Grid
  - Center Line (C.L.) Grid
  - Trailing Edge (T.E.) Grid

- **The splitting of this cap grid has thus far provided sufficient robustness in generating a broad range of rotor tip caps.**

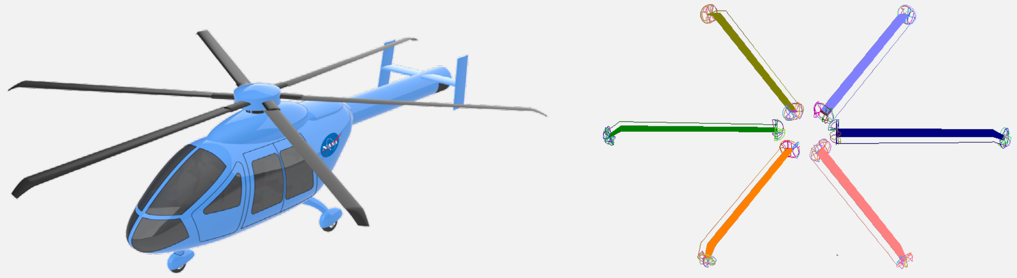


Rapid Rotor Grid Generation Examples

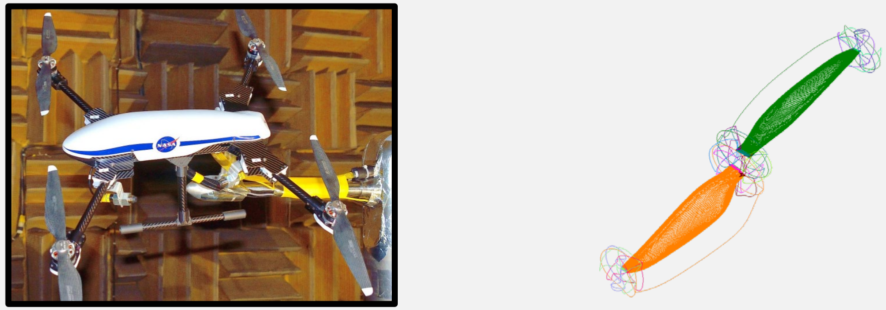
1:4.71 Scaled S-76



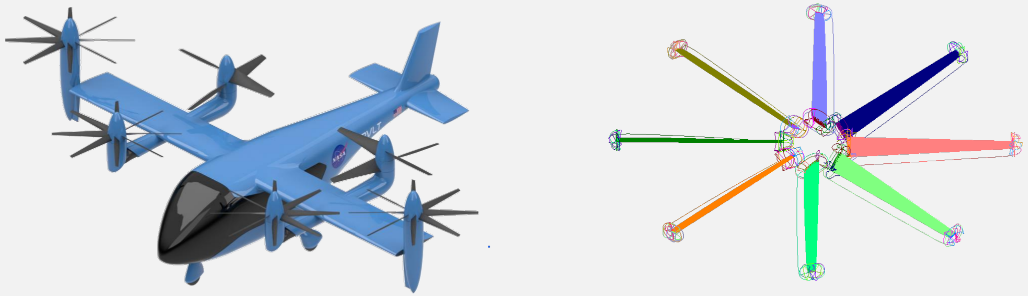
NASA Urban Air Mobility Reference Vehicle (Quiet Single Main Rotor)



SUI Endurance



NASA Urban Air Mobility Reference Vehicle (Multi-Tiltrotor)



- **We've tested grid generation against multiple rotors.**
  - Time to generate cases reduces from multiple *days* to a few *seconds*

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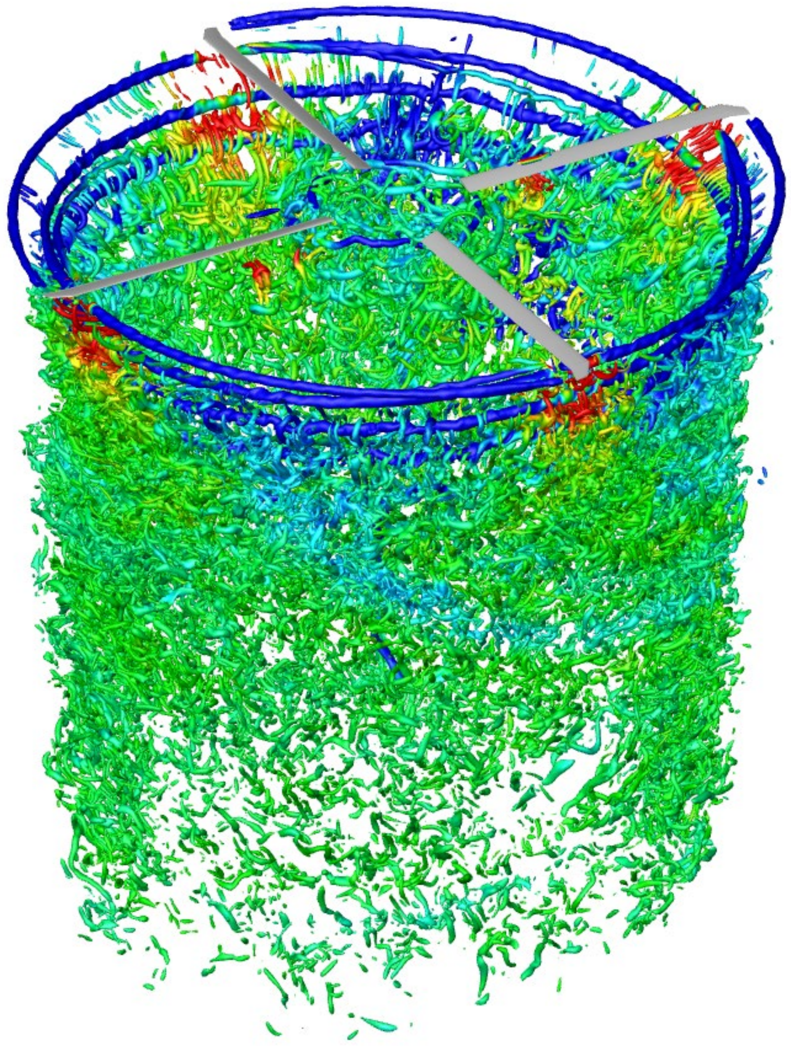
S-76 Validation Study

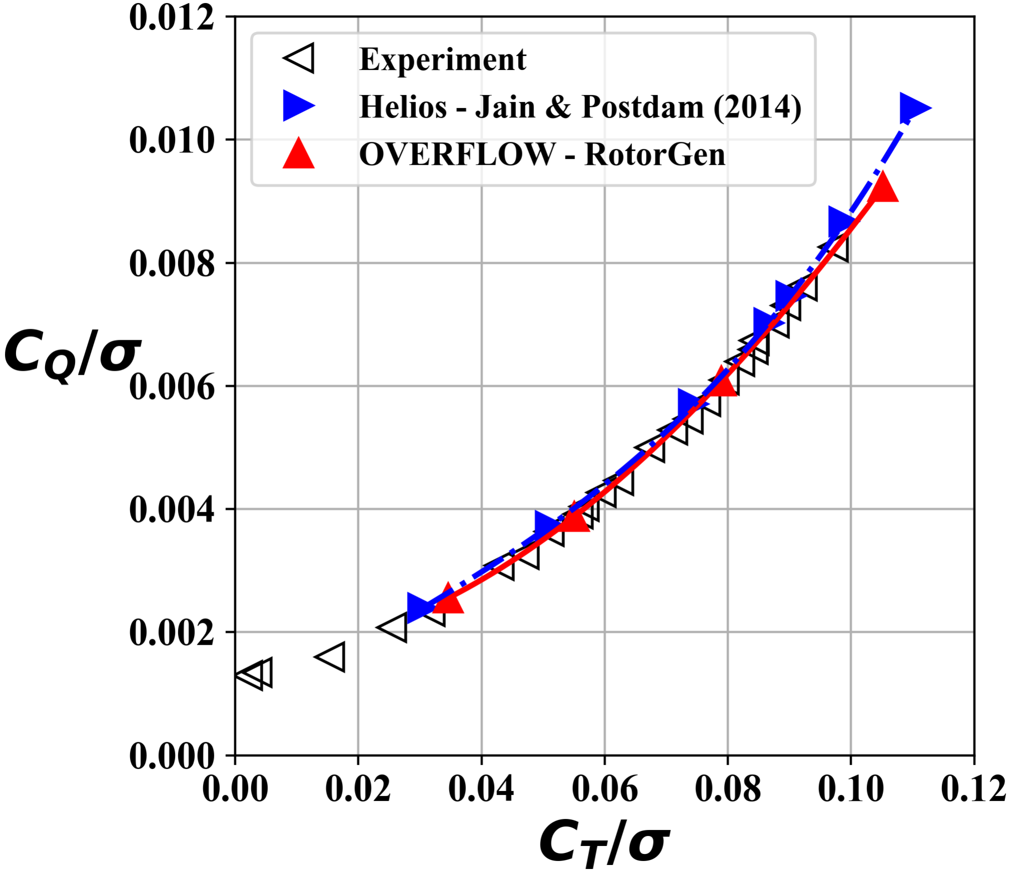
- **RotorGen was leveraged to complete a collective sweep for an S-76 hovering rotor.**
  - Four collectives are simulated: 4, 6, 8, 10 degs.
  - Radius: 4.67 ft, Tip Mach: 0.61

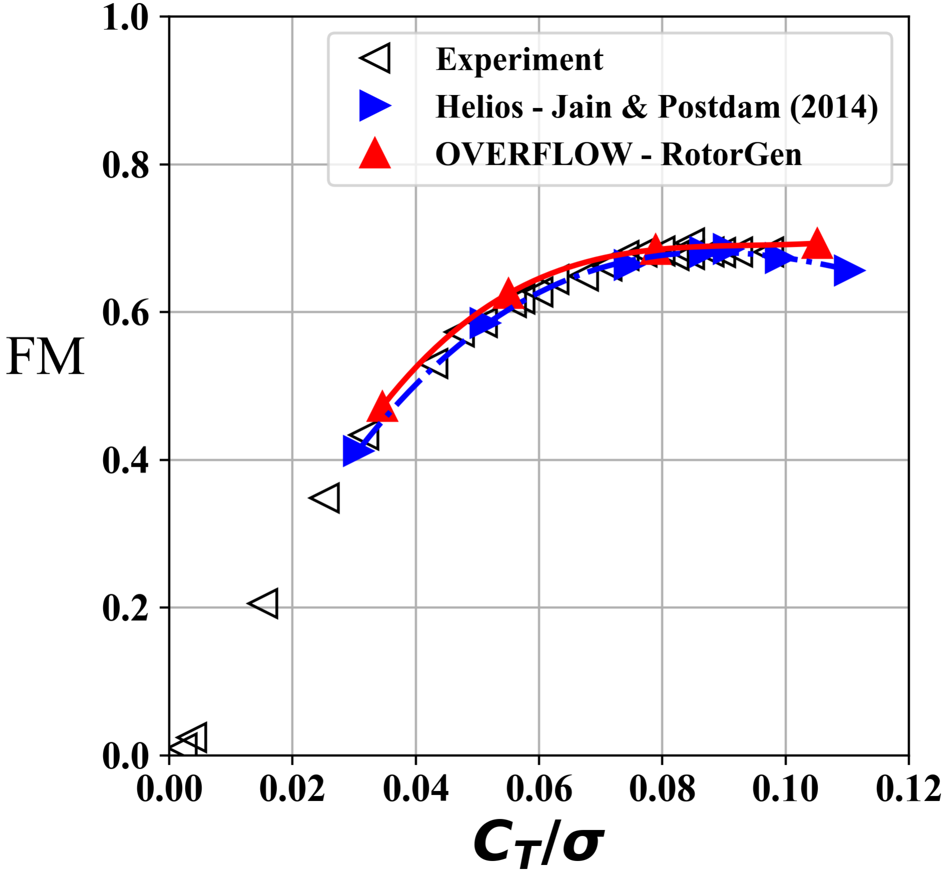
- **Cases are generated using conceptual design-level definitions.**
  - 5 spanwise rotor definitions
  - 3 airfoil files: SC1013R8, SC1095R8, and SC1095

- **CFD solutions are validated against both experimental measurements and CFD simulations.**
  - Balch, David T. "Experimental study of main rotor/tail rotor/airframe interaction in hover." *Journal of the American Helicopter Society* 30.2 (1985): 49-56.
  - Jain, Rohit K., and Mark A. Potsdam. "Hover predictions on the Sikorsky S-76 rotor using Helios." *52nd Aerospace Sciences Meeting*. 2014.



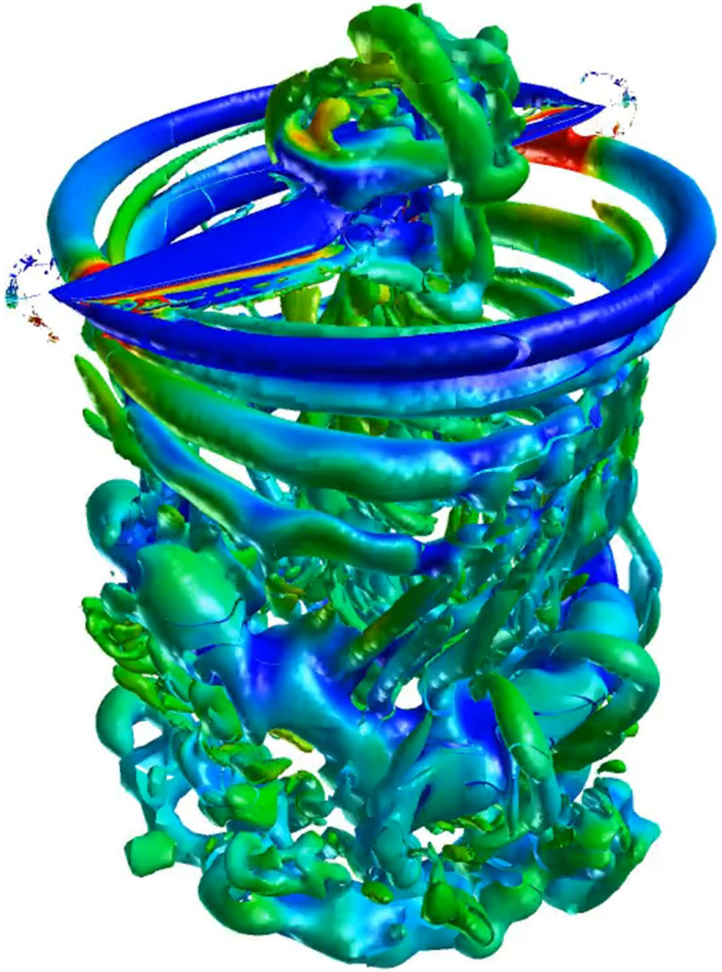
S-76 Performance Coefficients and Figure of Merit



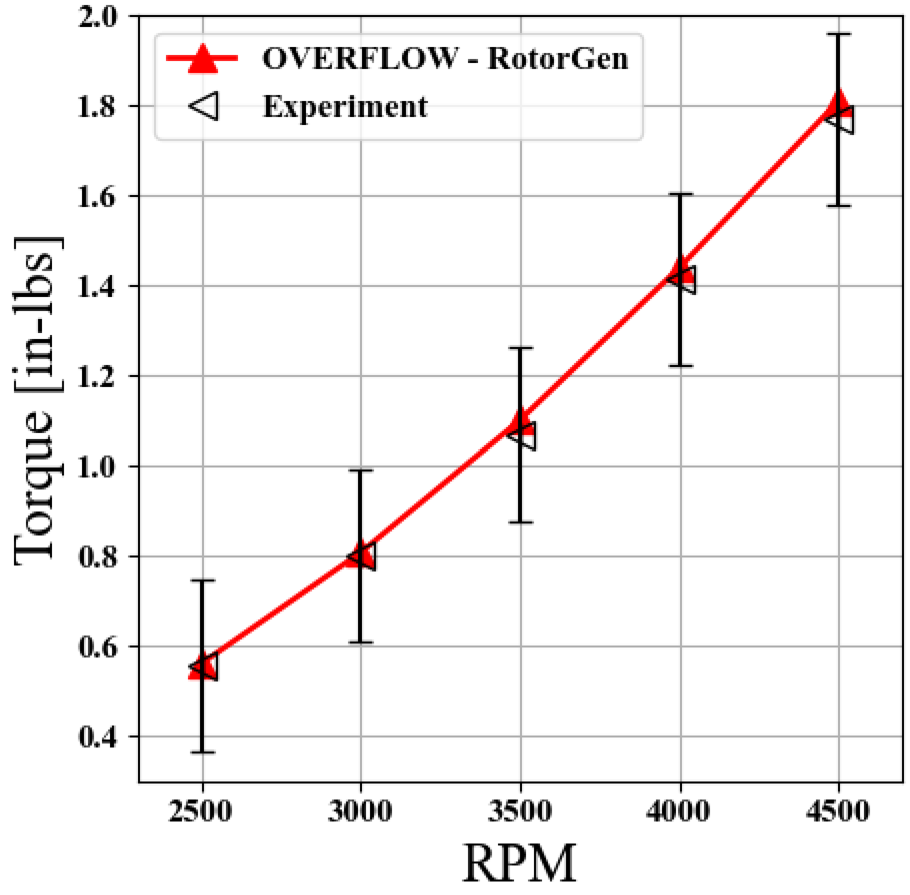


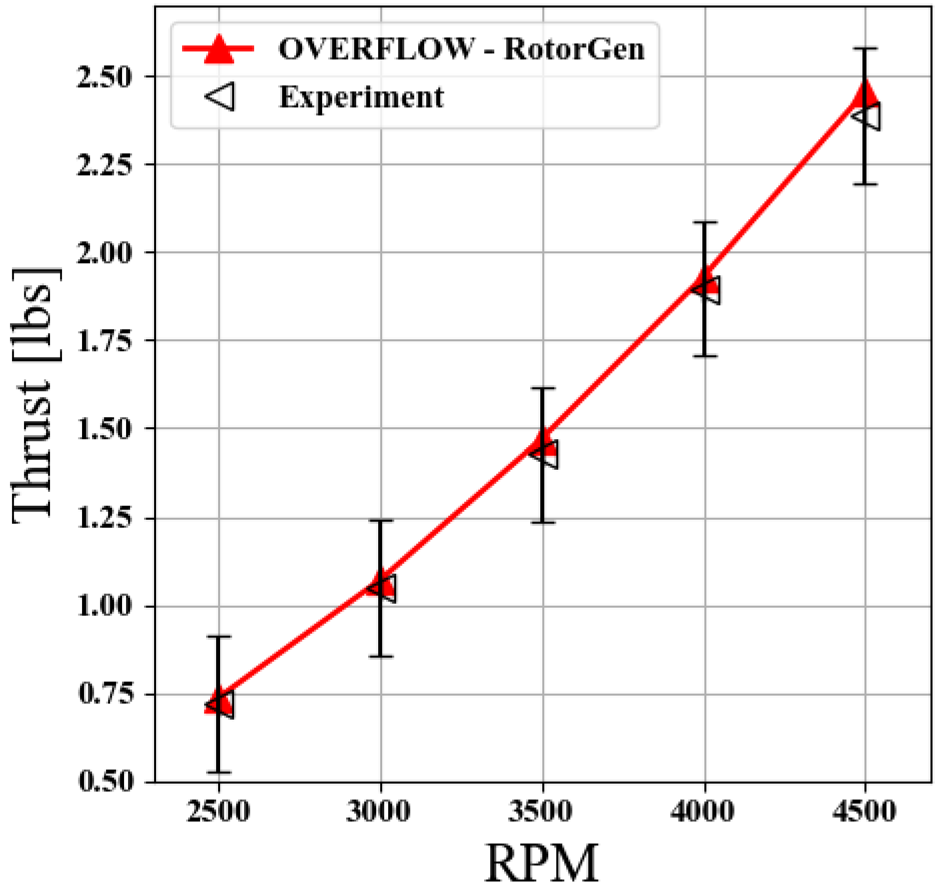
SUI Endurance Validation Study

- **RotorGen was leveraged to complete an RPM sweep for an SUI-Endurance hovering rotor.**
  - Five RPMs are simulated: 2500, 3000, 3500, 4000, 4500 RPM
  - Radius: 0.6 ft, Maximum Tip Mach: 0.3
- **Cases are generated using conceptual design-level definitions.**
  - 22 spanwise rotor definitions
  - 22 airfoil files generated from rotor blade scans
- **CFD solutions are validated against experimental measurements obtained by Carl Russell.**
  - Russell, Carl R., et al. "Wind tunnel and hover performance test results for multicopter uas vehicles." *American Helicopter Society (AHS) International Annual Forum and Technology Display*. No. ARC-E-DAA-TN31096. 2016.



SUI Endurance Performance Versus RPM

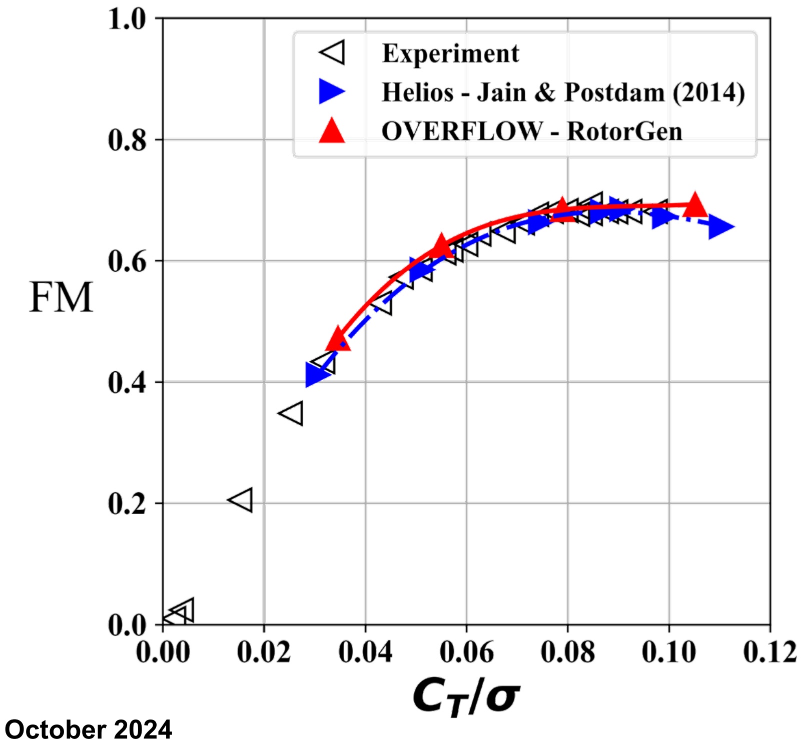




Summary of Validation Effort

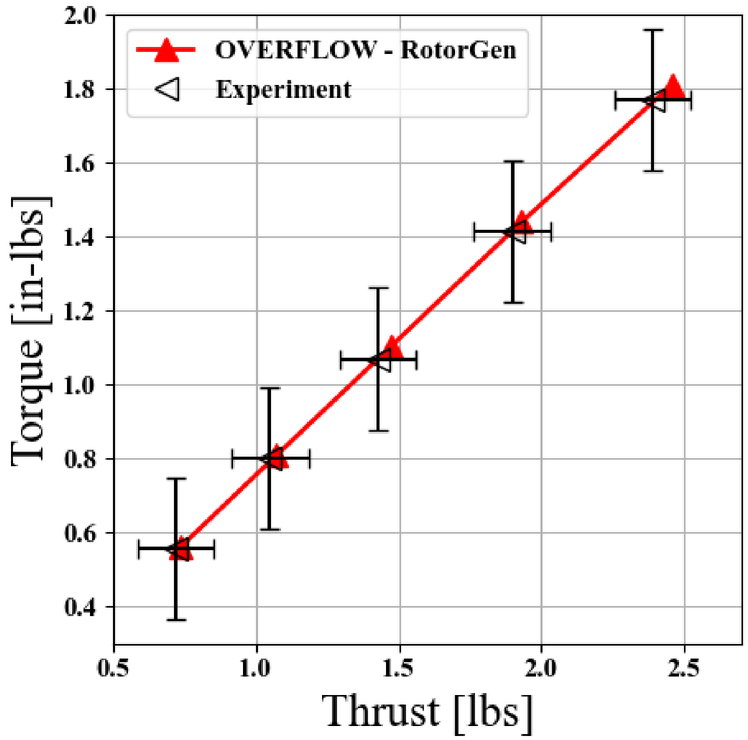
- **RotorGen-generated cases provided reasonably accurate hovering predictions.**
- **Hovering performance predictions were achieved for various rotor geometries and scales.**

S-76



	S-76	SUI
Radius	4.67 ft	0.6 ft
Tip Mach	0.6	0.15 - 0.3
Blades	4	2

SUI



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Concluding Remarks

- **Thus far, this effort has completed several key, initial tasks.**
  - A robust, high-level procedure for generating rotor grids has been identified.
  - This procedure has been validated for two hovering rotor performance predictions.

- **In the near term, the preliminary validation effort will be expanded to include a broadened range of applications.**

- **As next steps, we plan to expand RotorGen's capability to include the automation of coupling between CAMRADII and OVERFLOW for aeroelastic modeling and rotor trimming.**

- **The long-term objective of this effort is to publicly release RotorGen.**

- **This effort requires feedback from the community.**

Acknowledgements

- RVLT management for funding support in this effort
- NASA Ames Aeromechanics branch for help understanding conceptual design rotor definitions
- Ethan Romander for support in reviewing both OVERFLOW input files and generated grids
- Carlos Pereyra for significant contributions with code generation
- CGT group for assistance in grid generation