NASA Hover Tests: Overview and Plans

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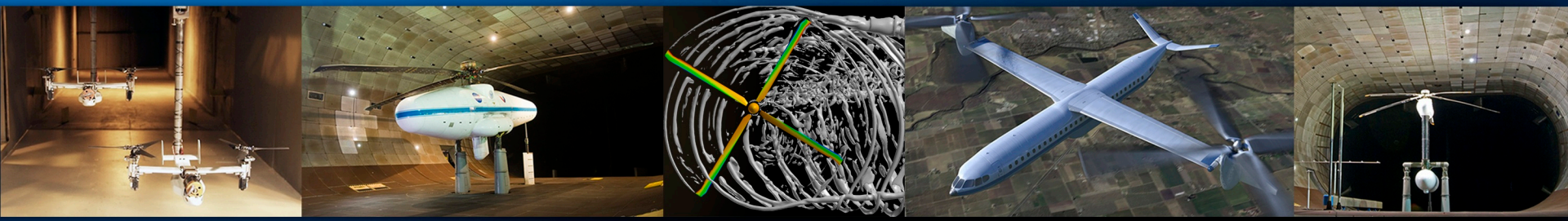

Background

- NASA and the Army began developing plans for a fundamental hover experiment in FY13
  - To address perceived need for well-documented hover data (for analytical validation)
- Preliminary plans and recommendations were presented at 2014 AIAA Aviation meeting
  - Test objective, rotor and facility options, key measurements identified
- Test plans have been further developed based on analysis and experimental considerations/constraints

- This presentation provides an overview of the proposed test, including current status of the planning activities

Summary Up Front

- NASA's Revolutionary Vertical Lift Technology (RVLT) Project and the Army continue to support planning for a fundamental hover test
  - Hover Test milestones included in RVLT's Project Plan
  - Notional date of December 2017 for testing

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  - Open-source airfoils/planform
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- Notional test date at risk due to funding limitations
  - Currently no NASA FY16 funding for hardware purchases
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Outline

- Hover Test Objective and Planning Considerations
- Proposed Rotor System
- Proposed Facility
- Proposed Measurements
- Summary

Hover Test Objective

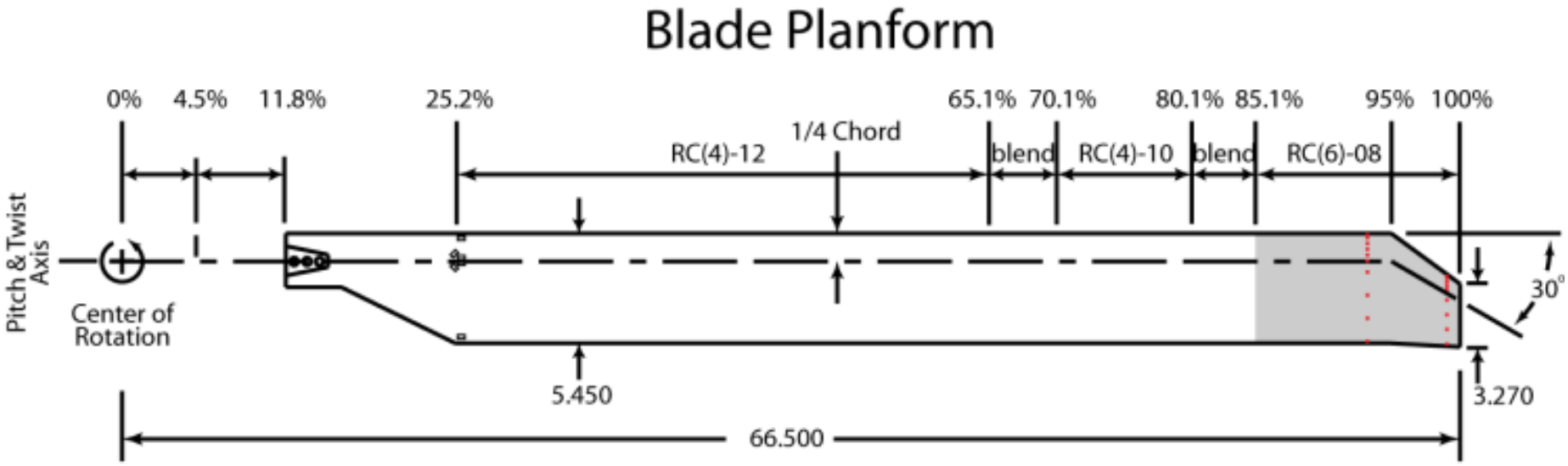
Acquire key experimental data for a hovering rotor of sufficient quality and quantity to allow validation of SOA hover analysis codes. Once validated, these codes should be able to predict hover performance in free air.

Hover Test Planning Considerations

- Rotor should be representative of “modern” multi-bladed helicopter with consistent and documented properties
- Test measurements should be sufficiently accurate for CFD validation (e.g. FM = +- .005) and comprehensive enough to ensure correct physics are represented (airloads, wake geometry, etc)
- Experimental uncertainties due to effects that aren’t easily measurable (facility walls and Reynolds number) should be minimized
- Existing NASA/Army hardware and facilities should be utilized as much as possible (for cost and accessibility reasons)

Proposed Rotor System

- New 4-bladed rotor set based on Army PSP rotor design
  - Approximately 11-ft diameter, RC series airfoils, -14 deg linear twist, swept tip
  - One (or more) blades with sufficient pressure instrumentation to determine airloads
  - One heated blade for transition measurements
  - Matched (measured) structural properties
  - Capable of higher tip Mach numbers (up to .675)



Proposed Rotor System

- Rotor System Next Steps
  - Finalize pressure instrumentation and transition measurement requirements
    - One or multiple blades?
    - Consistent with proposed pressure data acquisition system
  - Determine critical design loads based on analysis and previous test data
  - Develop SOW and procurement strategy

Test Facility Evaluation

- Two NASA facilities considered for hover test
  - Rotor Test Cell (RTC) at NASA Langley
  - NFAC 80- by120-Ft Wind Tunnel (80x120) at NASA Ames

- CFD used to estimate facility effects on hover measurements
  - Detailed OVERFLOW calculations by Neal Chaderjian[1] presented at 2015 AHS Forum
  - 10-ft diameter UH-60 rotor
  - Comparisons of Figure of Merit (FM) and streamlines with free air calculation

- [1]Chaderjian, N. M., and Ahmad, J. U., "Navier-Stokes Assessment of Test Facility Effects on Hover Performance," Proceedings of the American Helicopter Society 71st Annual Forum, Virginia Beach, VA, May 5-7, 2015.

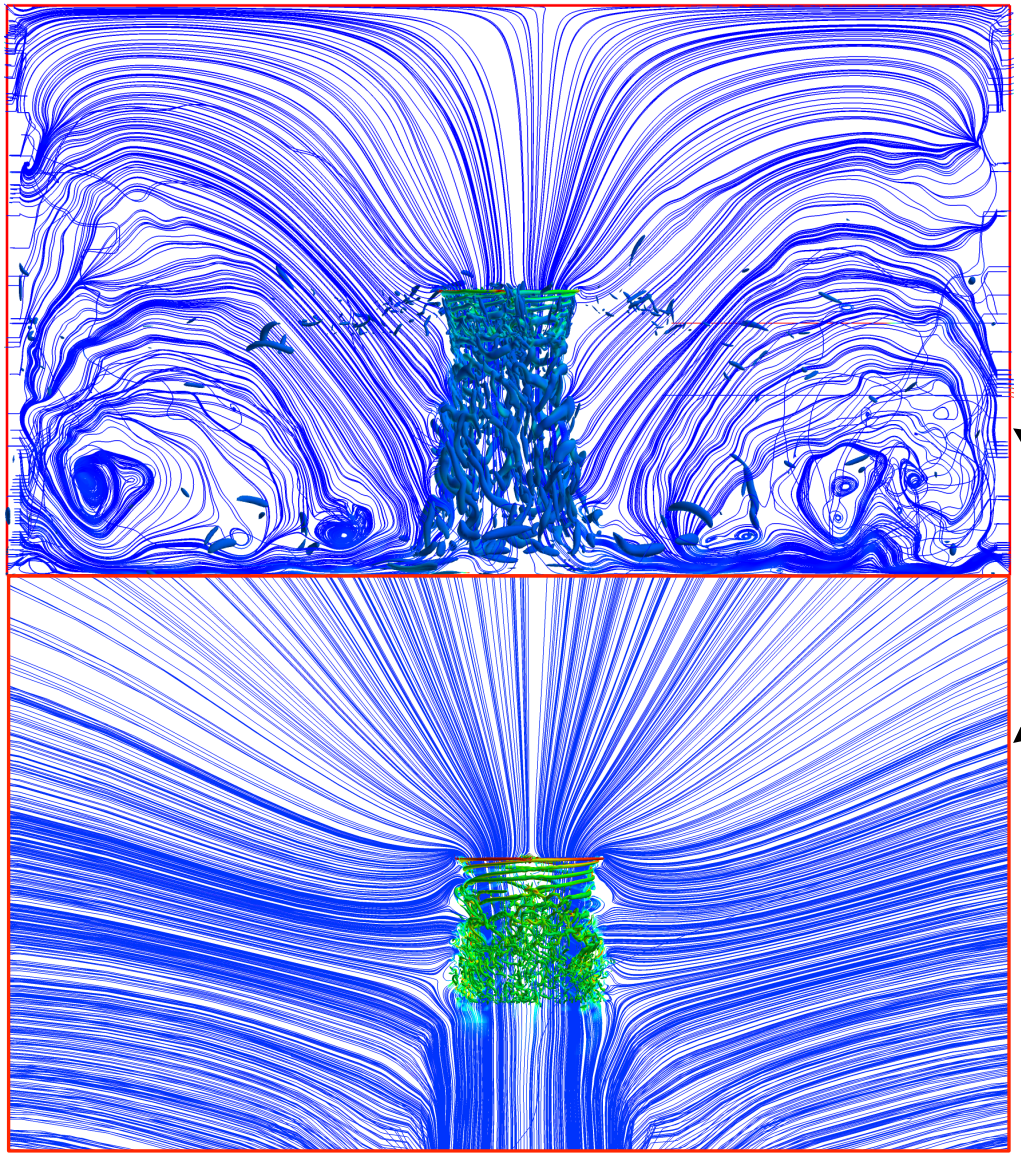
Candidate Facilities

Rotor Test Cell (RTC), NASA Langley

National Full-Scale Aerodynamics Complex (NFAC) 80x120 Ft Wind Tunnel, NASA Ames

Rotor in RTC – OVERFLOW

RTC L-L Section



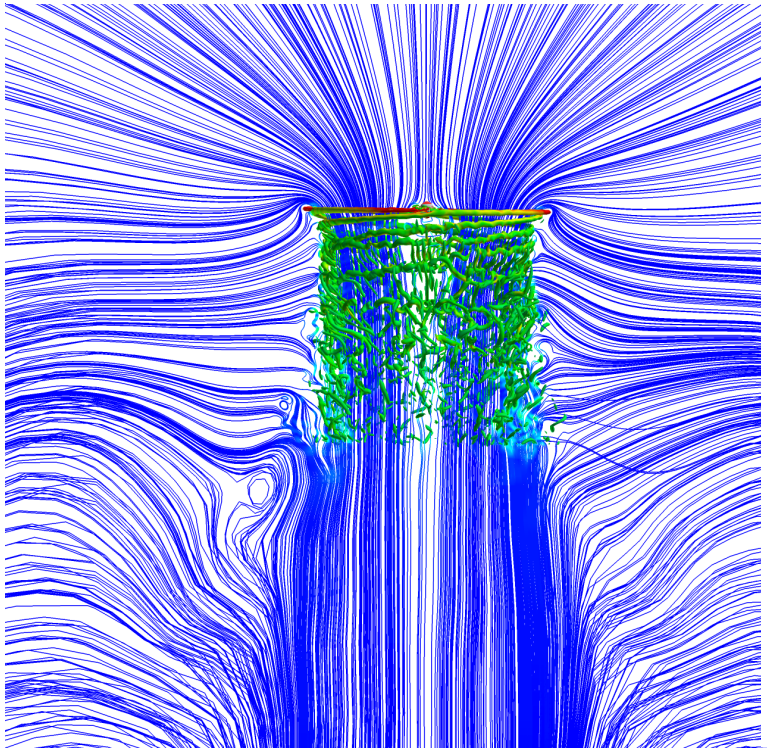
Free Air

Significant inflow differences

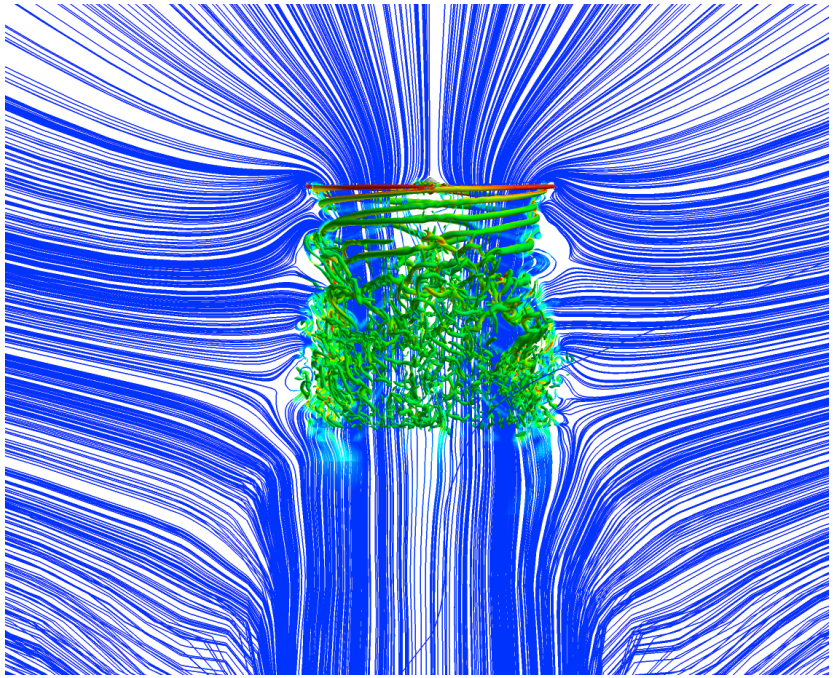
Rotor in 80x120 WT – OVERFLOW

- Flow structure is very similar between 80x120 and Free Air cases

Top view: NFAC 80x120 Wind Tunnel



Side view: Free Air



Summary of CFD Results

Facility	FM	Difference
Free Air	0.715	0.00%
Rotor Test Cell	0.678	-4.90%
80x120, Airplane Mode	0.715	-0.14%
80x120, Helicopter Mode		
20 ft above floor	0.722	0.98%
40 ft above floor	0.714	-0.14%
60 ft above floor	0.711	-0.56%

- CFD results (updated from Forum paper) show 5% FM differences in RTC and 0-1% in 80x120

Proposed Facility

- NFAC 80- by 120-Foot Wind Tunnel using Army ARTS rotor test stand
  - Rotor mounted in helicopter mode configuration for ease of operation
  - Existing Army ARTS rotor test stand compatible with NFAC and proposed rotor
  - Facility interference effect less than 1% on FM

- Facility Next Steps
  - Finalize rotor mounting height
    - Trade-off between facility interference and operational issues
    - Measurement system requirements will also impact decision
  - Begin preliminary design of test stand mounting hardware
  - Begin measurement systems development

Proposed Measurements

- Key measurements and priorities have not changed significantly since 2014
- Primary change is upgraded priority for transition measurement
  - Combination of rotor design and small scale suggests that rotor flow will be transitional
  - Since CFD predictions of transition are still poor, accurate transition location measurements are critical (IR thermography)
  - Data will be acquired both with and without trip dots (to trip flow to turbulent)

- Measurement Priorities
  - Priority 1: Must have
  - Priority 2: Highly desirable
  - Priority 3: Nice to have

Proposed Measurements

Measurement	Measurement Device/Technique	Min Sample Rate	Comments	Priority
rotor forces and moments	6-component balance	64/rev	Need high accuracy	1
shaft torque	shaft gauge	64/rev	Need high accuracy	1
blade airloads	Kulites	512/rev	8-10 radial stations, 20 taps per station = 160-200 taps	1
transition location	IR thermography		need 1/rev, 4096(?)/rev signal; 1 (?) camera; one blade	1
3D wake geometry	RBOS or TBD		verify wake symmetry; determine 3D position of wake filaments; 3(?) cameras	1
blade deformation	photogrammetry?		need 1/rev, 4096(?)/rev signal; 1(?) cameras; ALL blades measured at one (or 2) azimuths	1
rotating blade pitch (collective, cyclic)	rotary pots	64/rev	At least one blade, prefer measurements on all blades	1
atmospheric conditions			needed for density calculation, sound speed calculation	1
pitch link loads	strain gauges	64/rev		1
blade structural loads	strain gauges	64/rev	SOF only; 1 station, 3 gages	1
3D velocity field in a plane	stereo PIV		need 1/rev, 4096(?)//rev signal; 2 cameras; pulsed laser; ROI TBD	2
acoustics	microphones	512/rev	rake with multiple measurements	2
3D velocity field in a volume	tomographic PIV		need 1/rev, 4096(?)/rev signal; 2 cameras; pulsed laser; ROI TBD	3
shear stress	oil film interferometry	n/a	smooth, partially reflective blade surface; one blade	3

Proposed Measurements

- Measurements Next Steps
  - Finalize pressure transducer requirements for airloads determination
    - Determine method for data acquisition
  - Verify rotor performance measurement accuracy (calibration)
  - Choose measurement approaches for blade deformation and wake geometry
  - Demonstrate capability for transition measurements, including boundary layer tripping
  - Begin planning for acquisition of all measurements in NFAC 80x120

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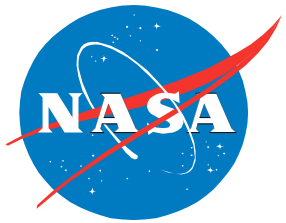
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