# Status of NASA/Army Hover Test

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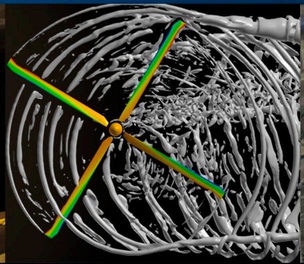
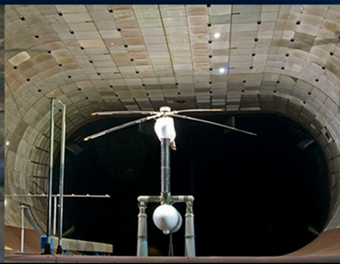
2018 AIAA Aerospace Sciences Meeting
AIAA SciTech Forum 2018– January 8-12, 2018







# 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 and 2016 SciTech meetings
  - Test objective, rotor and facility options, key measurements
- Test plans have since been further developed based on analysis and experimental considerations/constraints

- This presentation provides
  - Recent progress and current status of the test planning effort
  - Overview of proposed test including anticipated data products for CFD validation

# Outline

- Hover Test Objective and Planning Considerations
- Current Approach
- Recent Progress/Status including schedule
- Test Description
  - Rotor System, Test Stand, Facility
  - Key Measurements
- Data Products for CFD Validation
- 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)

# Current Approach

- Develop new Hover Validation and Acoustic Baseline (HVAB) blade set based on PSP rotor design
  - 2 pressure instrumented blades, 1 strain gaged blade
  - 3 other blades with functional heating elements to enhance IR transition measurements
  - Matched structural properties
  - Capable of higher tip Mach numbers (.675) using upgraded articulated hub

- Test in NFAC 80- by 120-Foot test section to minimize facility effects on performance
  - Use existing Army ARTS test stand
  - Mount rotor at 32 to 40 ft above floor (TBD) in wake down configuration

- Acquire key measurements for CFD validation
  - Performance, airloads, transition location, wake info, blade deflection, etc

- Acquire data sets for both natural and tripped boundary layer

# Recent Progress/Status

- Contract awarded for new HVAB blade set
  - Delivery expected in late summer 2018
- CFD computations completed to evaluate configuration effects of fuselage and facility (Rohit Jain, SciTech 2018)
  - Predictions show proposed configuration has relatively small effect on Figure of Merit (< 0.006)
- Detailed test planning well underway and test preparations have begun
  - Test stand refurbishment and checkout
  - Test stand integration into NFAC
  - Implementation of non-intrusive measurements in NFAC

# Test Schedule

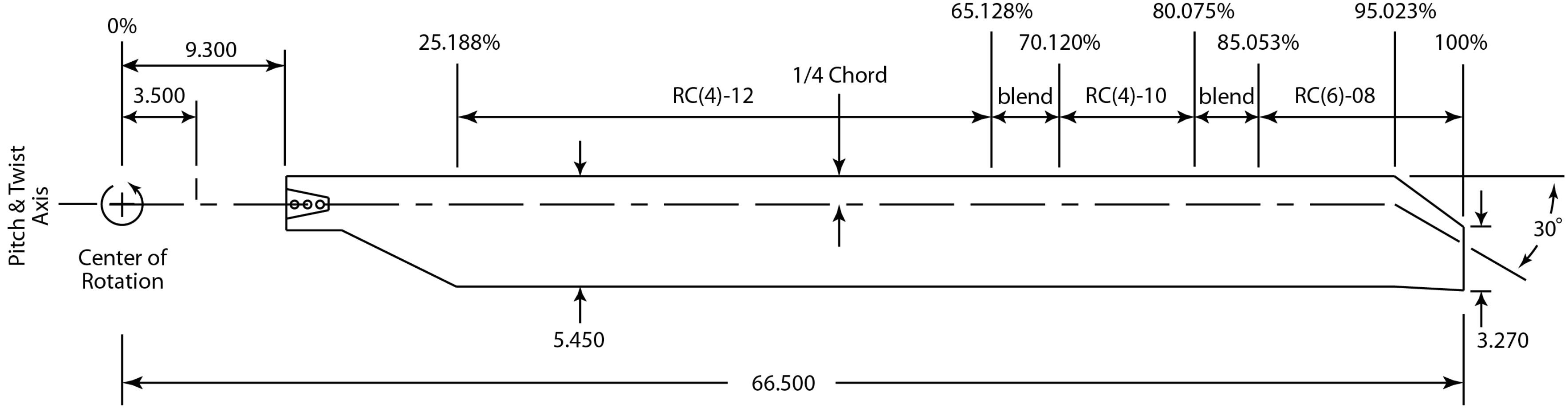
- Current estimates show testing to begin Fall 2019*

| | CY2017 | CY2018 | | | | CY2019 | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Task** | **Q4** | **Q1** | **Q2** | **Q3** | **Q4** | **Q1** | **Q2** | **Q3** | **Q4** |
| **HVAB Blade Design/Fab** | | | | | | | | | |
| **ARTS Stand Refurbishment** | | | | | | | | | |
| **Rotating Checkout w/ Blades** | | | | | | | | | |
| **NFAC Integration** | | | | | | | | | |
| **Hover Testing in NFAC** | | | | | | | | | |

* Dependent on availability of out-year funding

# Test Description - HVAB Blades

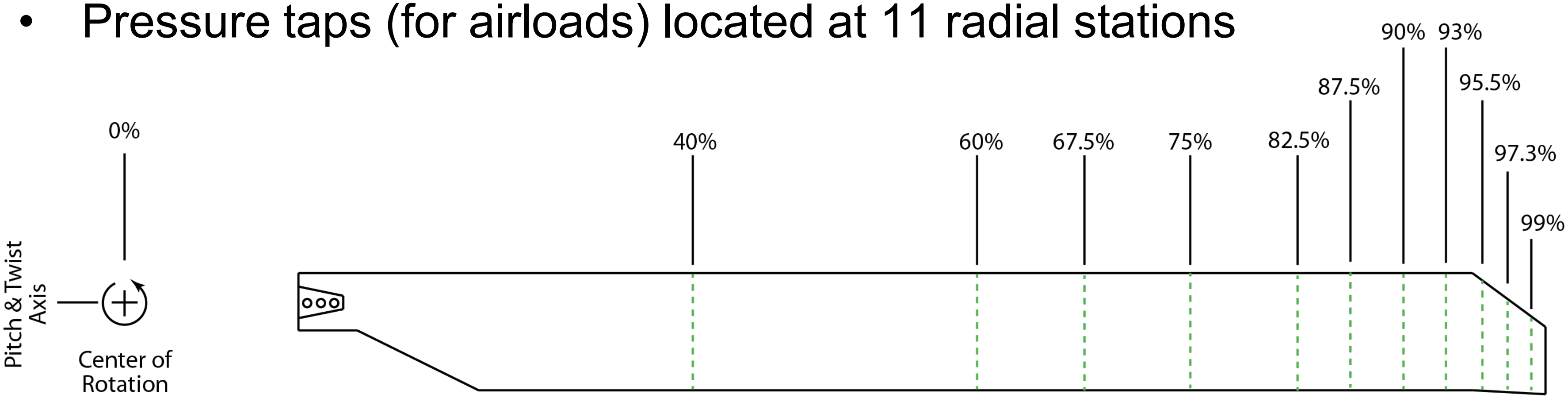
- Identical to Army PSP rotor except for root attachment location




| | |
|---|---|
| **Radius** | **66.5 inches** |
| **Reference chord** | **5.45 inches** |
| **Tip taper ratio** | **60%** |
| **Tip sweep (quarter chord)** | **30 deg. at 95% R** |
| **Airfoils** | **RC series** |
| **Number of blades** | **4** |

# Test Description - HVAB Blades

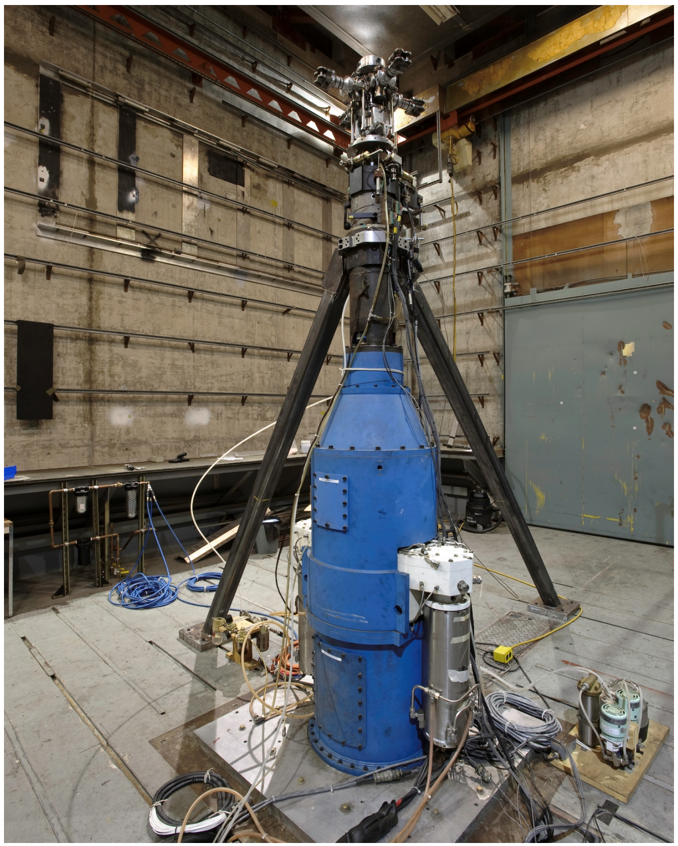
- Strain-gaged and pressure-instrumented blades
- Pressure taps (for airloads) located at 11 radial stations




| Blade Number | Blade Type | Blade Instrumentation | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Strain Gages | | | | Pressure Transducers | | | Tip LED | Active Heater | RTDs |
| | | Beam | Chord | Torsion | Radial Stations | Total | Radial Stations | None | | | |
| SN000 | Process | | | | | | | X | | X | |
| SN001 | Production | X | X | X | 1 | | | X | X | X | X |
| SN002 | Production | X | X | X | 1 | | | X | X | X | X |
| SN003 | Production | X | X | X | 1 | | | X | X | X | X |
| SN004 | Production | X | X | X | 1 | 187 | 11 | | X | | X |
| SN005 | Production | X | X | X | 1 | 51 | 14 | | X | | X |
| SN006 | Optional | X | X | X | 4 | | | X | X | X | X |

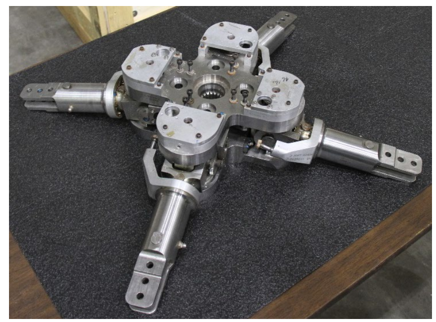
# Test Description – Test Stand/Facility

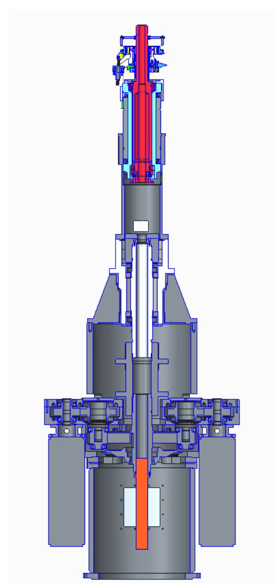
- Army ARTS test stand in NFAC 80- by 120-Foot test section



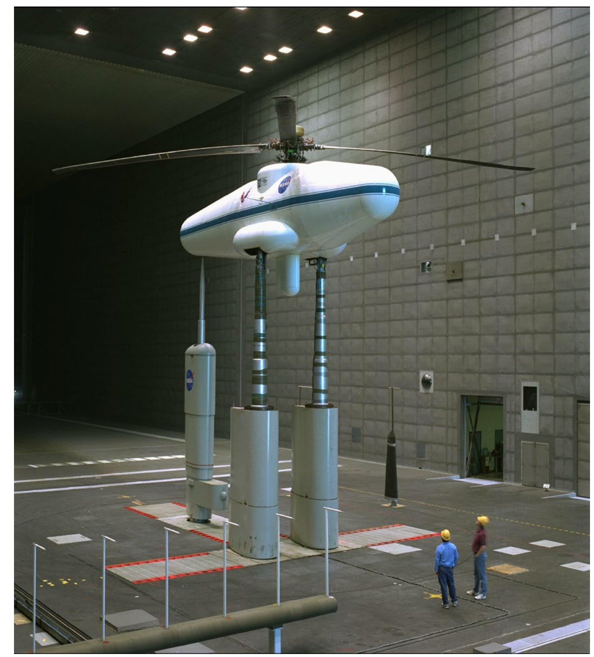
ARTS Test Stand in Hover Chamber

Articulated Hub





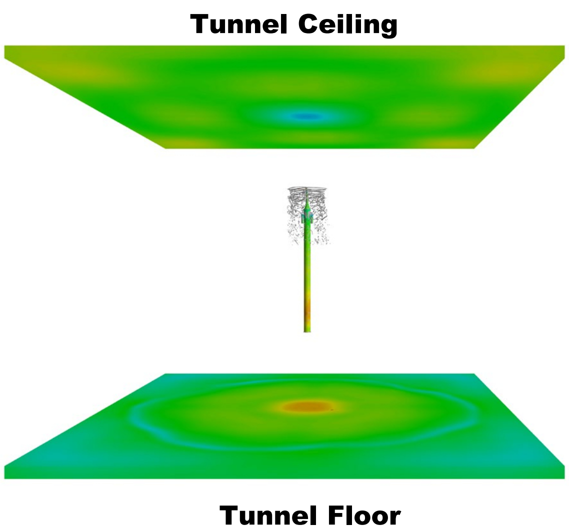
NFAC 80- by 120-



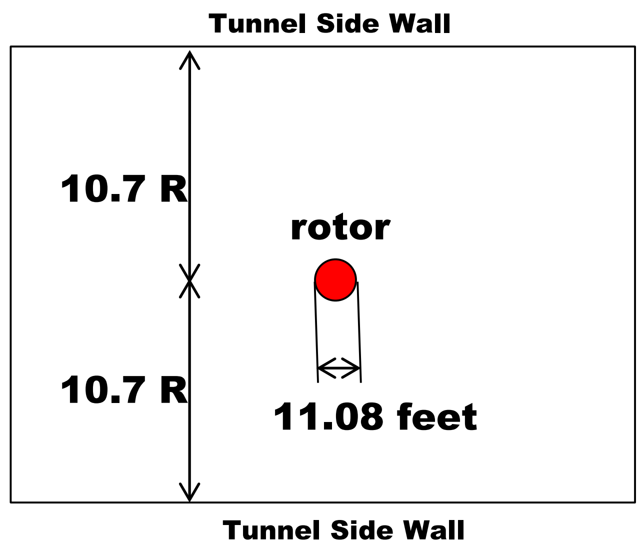
# Test Description – Test Stand/Facility

- Relative Scale

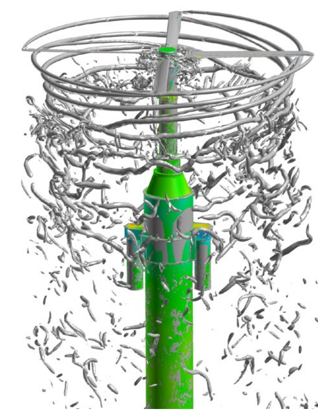
Rotor/Stand relative to floor/ceiling (Jain)




Rotor relative to side walls– top view




Rotor relative to test stand (Jain)



# Test Description – Key Measurements

- Rotor Thrust and Torque (rotor balance and flex coupling)
- Blade Root Motion (root collective, flap, lag) and Blade Deflections (Hall effect transducers, photogrammetry)
- Blade Pressures (Kulites)
- Boundary Layer Transition Measurements(IR Thermography)
- Rotor Wake Geometry (shadowgraphy)
- Rotor Vortex Properties (particle image velocimetry)

# Data Products for CFD Validation

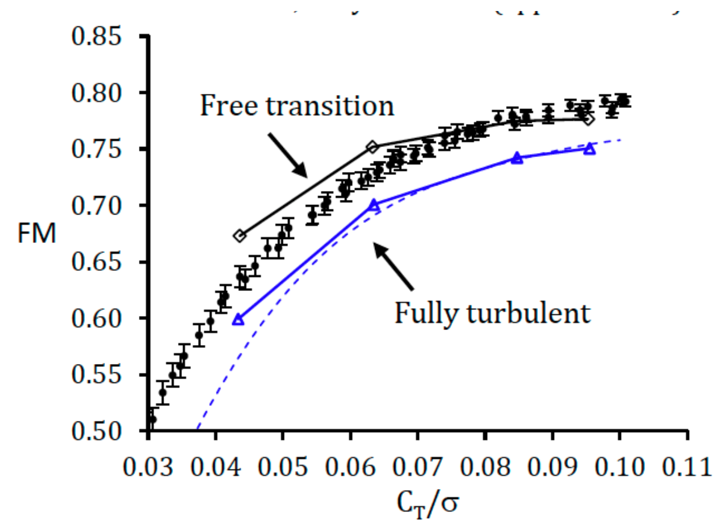
- Initial list of data products for CFD validation has been prepared
- Includes data needed to support CFD inputs as well as for validation
- Feedback on desired products is encouraged

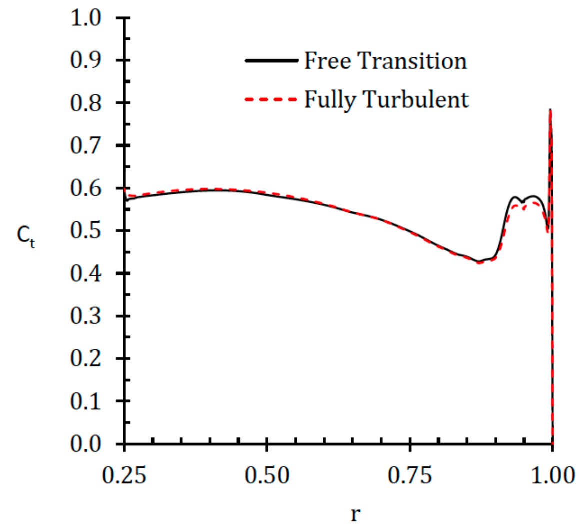
# Data Products for CFD Validation

- Data for CFD Inputs
  - Test Hardware Geometry
    - CAD model/grid of rotor blade OML (as-designed and as-measured)
    - CAD model/grid of test stand and attachment hardware
    - Description of rotor hub and blade interface (final form TBD)
    - Description of 80- by 120-Foot Wind Tunnel and model location (final form TBD)
  - Rotor Operating Conditions and Blade Displacements (measured at each condition)
    - Tip Mach number (RPM, atmospheric conditions)
    - Blade root angles (blade root pitch/flap/lag)
    - Blade deflections (flap and twist vs r/R, photogrammetry) for multiple blades

# Data Products for CFD Validation

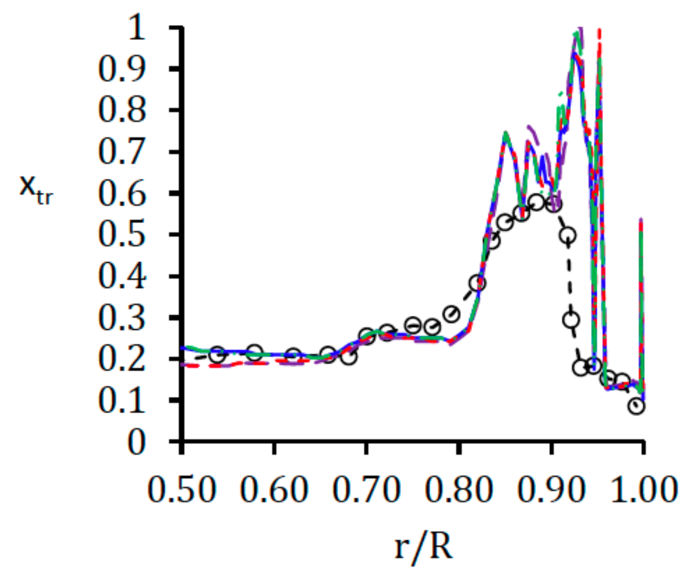
- Data for CFD Validation (at each condition)
  - Rotor Performance
    - Figure of Merit (thrust/torque, rotor balance/flex coupling) vs Ct/s
    - Ct/s vs collective
  - Blade Airloads
    - Kulite pressure transducers at 11 r/R stations, pressures plus integrated airloads

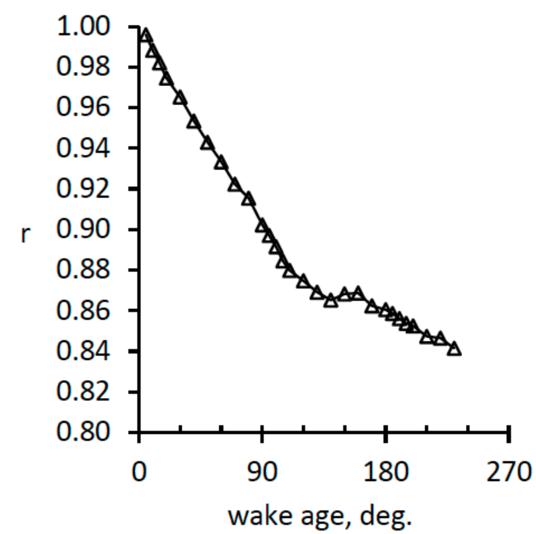


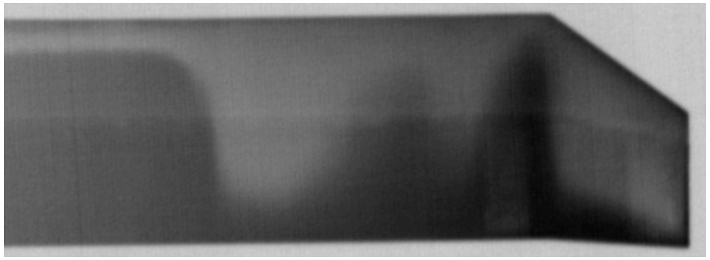



# Data Products for CFD Validation

- Data for CFD Validation (at each condition)
  - Transition Location (x/c vs r/R) upper and lower surfaces (multiple blades) (IR Thermography)
  - Tip vortex geometry (z/R and r/R vs wake age) (shadowgraph)

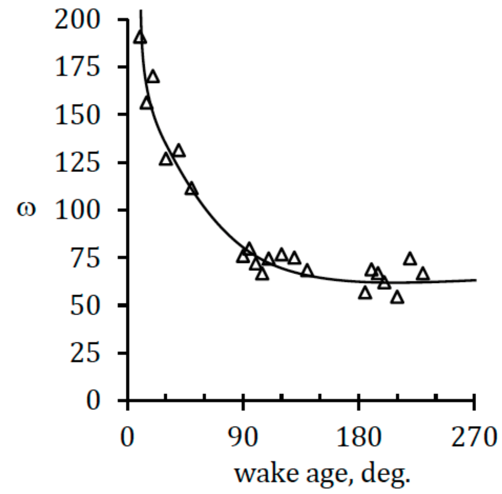


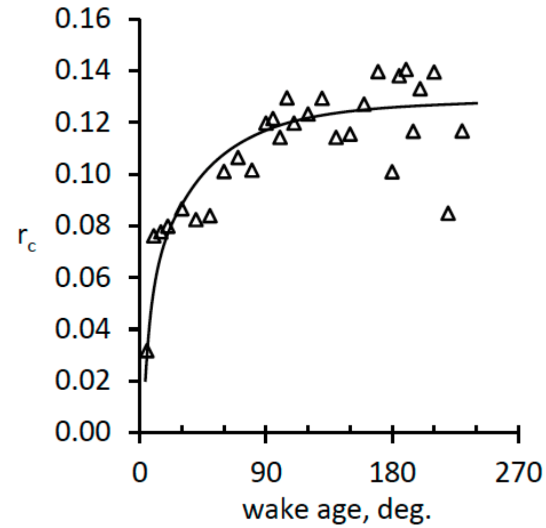



# Data Products for CFD Validation

- Data for CFD Validation (at each condition)
  - Tip vortex circulation, vorticity, and core size vs wake age (PIV)
  - Wake velocities and vorticity for different wake ages (PIV)



# Summary

- NASA/Army Hover Test planning and preparations are progressing well
- Current schedule shows hover testing in late CY2019
- Initial list of data products for CFD validation has been developed for review

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