



Fundamental Aeronautics Program

Subsonic Rotary Wing Project

Aeromechanics Overview

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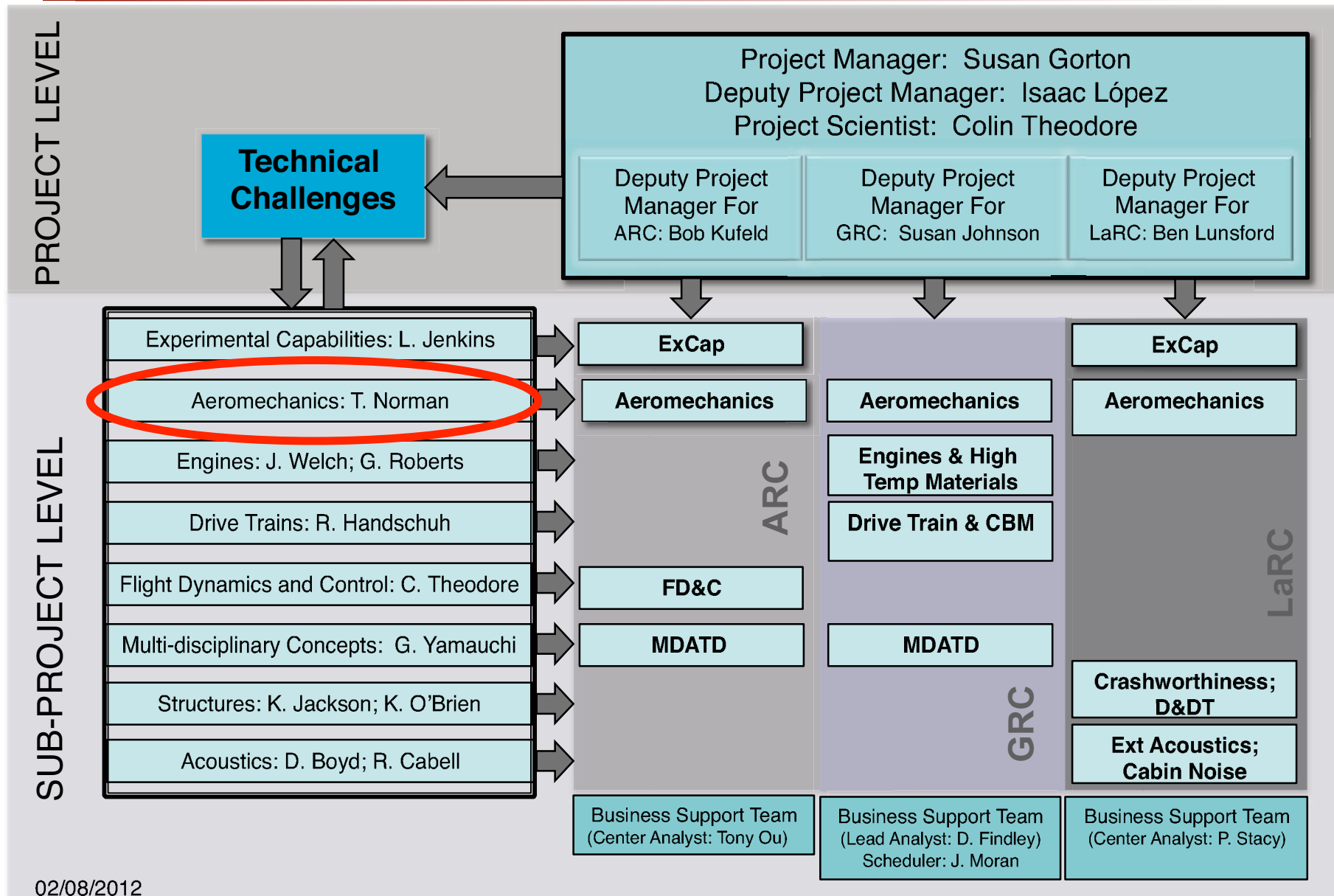


Outline

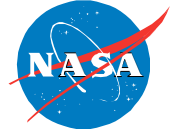


- Organization
- Aeromechanics Task Areas
- Aeromechanics Highlights
- Near-Term Plans
- Questions?

SRW Project Organization



SRW Aeromechanics

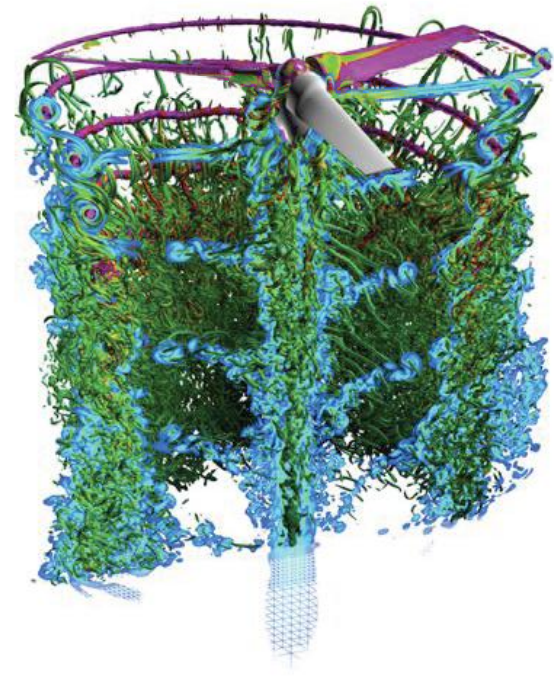


Objectives

- Advance the understanding of phenomena in aerodynamics, dynamics, and active control of rotorcraft in support of SRW Technical Challenges
 - Develop and validate first-principles tools
 - Acquire data for tool validation from small- and large-scale testing of existing and novel rotorcraft configurations



**UH-60A
Airloads Test**

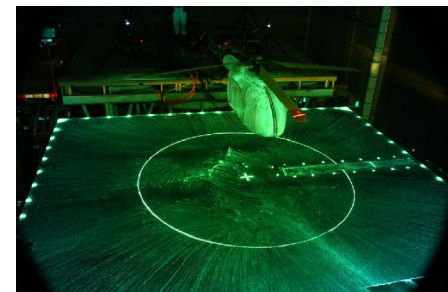


**Isolated tiltrotor in hover
(OVERFLOW)**

Aeromechanics Facilities



- Primary Facilities
 - ARC
 - Supercomputing Complex (NAS)
 - USAF National Full-Scale Aerodynamics Complex (NFAC) – 40x80
 - Army 7x10 Wind Tunnel
 - GRC
 - Icing Research Tunnel (IRT)
 - LaRC
 - 14- by 22-Ft Wind Tunnel (14x22) and hover test cell
 - Transonic Dynamics Tunnel (TDT)
 - 2x3 Tunnel

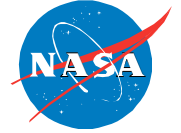


Aeromechanics Task Areas



- Aeromechanics sub-project organized into 6 interrelated task areas
 - CFD/CSD Tool Development and Applications
 - Icing
 - Active Rotors
 - Advanced Configurations
 - Rotor Aerodynamics and Interactions
 - Rotor Dynamics and Control

Aeromechanics Task Areas

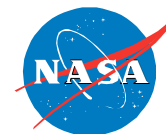


- CFD/CSD Tool Development and Applications
 - Structured (OVERFLOW)
 - Code enhancements, improved gridding, coupling methods, optimization, validation
 - Unstructured (FUN3D)
 - Code enhancements, improved gridding, coupling methods, optimization, validation
- Icing
 - LEWICE/ CFD developments
 - Experimental Research
- Active Rotors
 - Root pitch and on-blade flap (IBC, SMART)
 - Active Twist (ATR, STAR)
 - Flow control in rotating system

Aeromechanics Task Areas



- Advanced Configurations
 - Tiltrotor research, use of Tiltrotor Test Rig (TTR)
 - Slowed rotor compound research
- Rotor Aerodynamics and Interactions
 - Airloads
 - Drag reduction
 - Rotor/fuselage/tail interactions
 - Dynamic stall
 - Flow control in fixed system
 - Downwash/outwash
- Rotor Dynamics and Control
 - Oscillatory hub loads
 - Stability
 - Active Controller development



Research Areas to be Highlighted

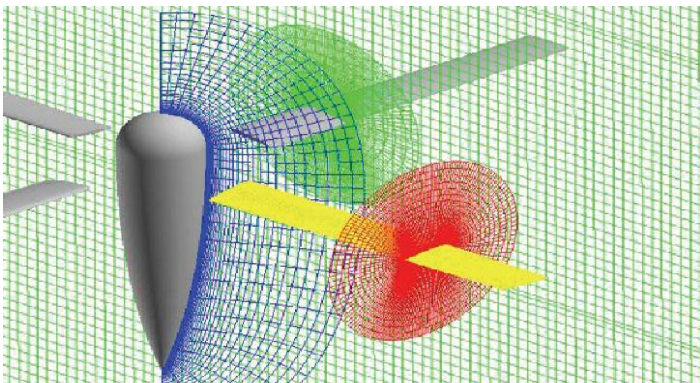
- Structured CFD Development and Applications*
- Unstructured CFD Development and Applications*
- **Rotorcraft Icing**
- **Apache Active Twist Rotor (ATR-A)**
- **Tiltrotor Test Rig Development**
- UH-60 Airloads Wind Tunnel Test Highlights*
- Fuselage Drag Reduction via Active Flow Control*
- **Rotor in Ground Effect (Downwash/Outwash)**

*Separate Presentation

Rotorcraft Icing



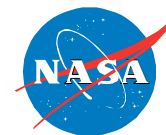
- Objective
 - Acquire key experimental data and develop computational methods to accurately predict the effects of ice accretion on rotor performance
- Approach
 - Develop high-fidelity coupled analysis capability (CFD/CSD and ice accretion codes)
 - Evaluate analysis capabilities using existing and new experimental data
 - Work closely with industry and university partners to best leverage NASA investment (NRA's, VLC/NRTC partnerships, VLRCOE collaboration)
- Recent Accomplishments
 - Completed 3 highly successful NASA-sponsored NRA's to develop and apply coupled CFD/ice accretion codes to rotor performance predictions



CFD Modeling

Oscillating Airfoil
Icing Test

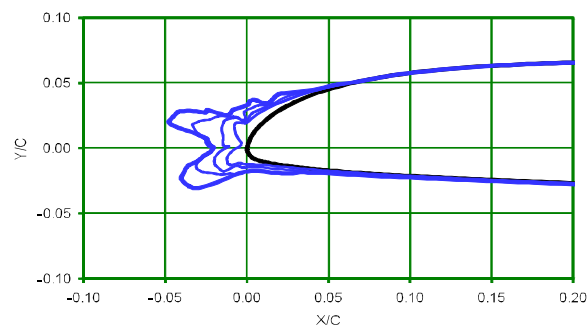




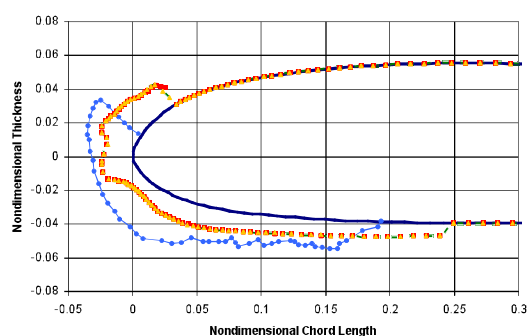
Icing NRA's

- Boeing
 - Loose-coupling of OVERFLOW-RCAS for rotor performance prediction with Lewice3D for thermal analysis and ice accretion (2D)
 - Performance and ice shapes compared with experimental hover/forward flight data
- Georgia Tech/Sikorsky
 - Integrated tool set (Python-based script) with CFD/CSD, grid generation, and ice accretion modeling. Stand-alone module for runback-refreeze characteristics.
 - Key computational parameters explored, preliminary results encouraging
- Penn State/Bell
 - Generalized unstructured CFD approach for simulating ice accretion on aircraft
 - Calculates air flow, droplet trajectories, surface-liquid flow, solidification, and computes deformed ice shape. Initial validation cases promising.

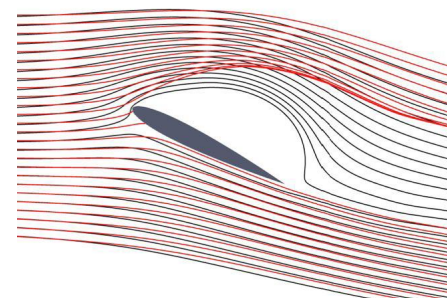
Boeing
Sequential Ice Build-up



GT/Sikorsky
Ice Shape Validation



Penn State/Bell
Droplet Trajectories



Icing Plans



- Evaluate new computational approach(es) for non-iced and iced rotor performance and ice accumulation predictions
 - Identify limitations in approaches and address needs for improved models and/or key experimental data (shedding, surface heat transfer prediction, collection efficiency)
 - Internal NASA evaluation and collaboratively with VLC/NRTC/VLRCOE
- Continue preparations for subscale rotor testing in Icing Research Tunnel (IRT) in 2013 (joint with VLC/NRTC)
 - Test will provide key data on rotor performance decrement, runback-refreeze phenomena, and ice shedding
 - In preparation for test, will develop improved methods to measure/document three-dimensional ice accretion shapes

Powered Force Model With Simulated Ice Shapes (1994)



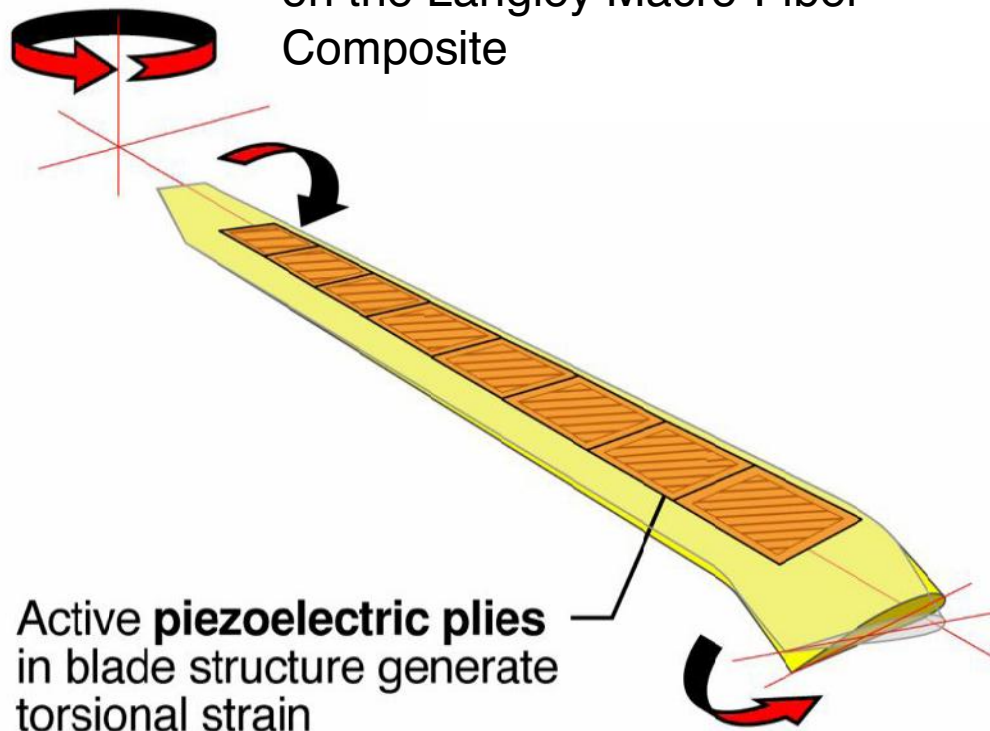
Apache Active Twist Rotor (ATR-A)



Joint Army/NASA Test Program

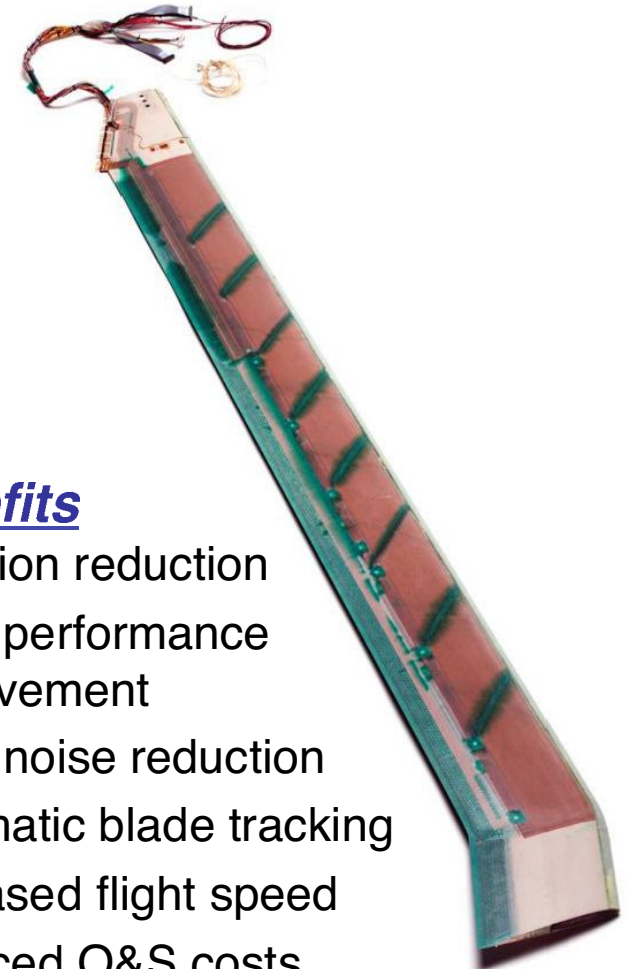
Objective

- Demonstrate active-twist control of a model-scale rotor system in NASA TDT
 - AH-64A Apache
 - Advanced, custom actuators based on the Langley Macro-Fiber Composite



Benefits

- Vibration reduction
- Rotor performance improvement
- Rotor noise reduction
- Automatic blade tracking
- Increased flight speed
- Reduced O&S costs



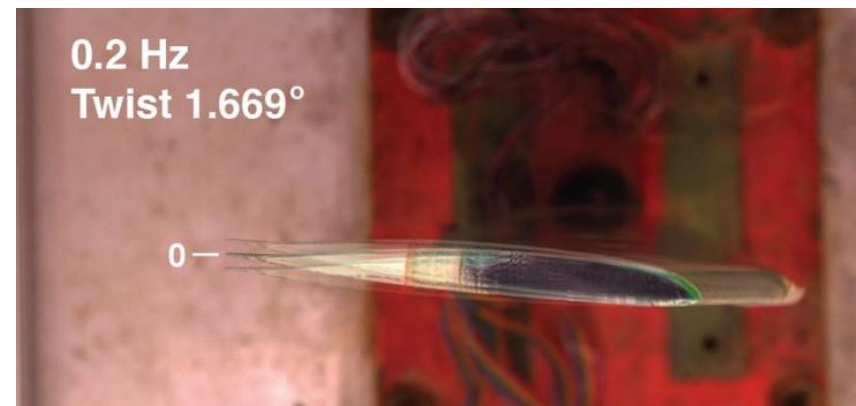
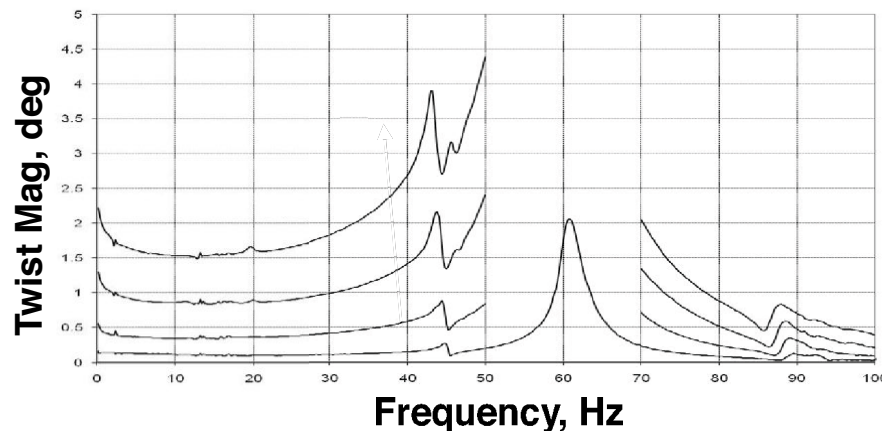
Active Twist Rotor (ATR)



Accomplishments and Future Plans

Joint Army/NASA Test Program

- One sample and 4 (of 6) test-quality ATR blades delivered
 - Complete blade set delivery expected in April 2012
- Blade response characterized through benchtop testing



- Testbed and data system checkout currently underway
- Projection Moiré Interferometry (PMI) acquisition techniques and analysis software specific to 4-quadrant application currently under development
- Hover testing planned for summer 2012
- Wind tunnel entry planned for October-November 2012

Tiltrotor Test Rig (TTR)



- **Objective**

- Fabricate new Tiltrotor Test Rig (TTR) to test large-scale proprotors in axial, transition, and edgewise flight
 - Fills NASA, DOD, and industry gap for testing large-scale tiltrotor concepts (LCTR, JMR)

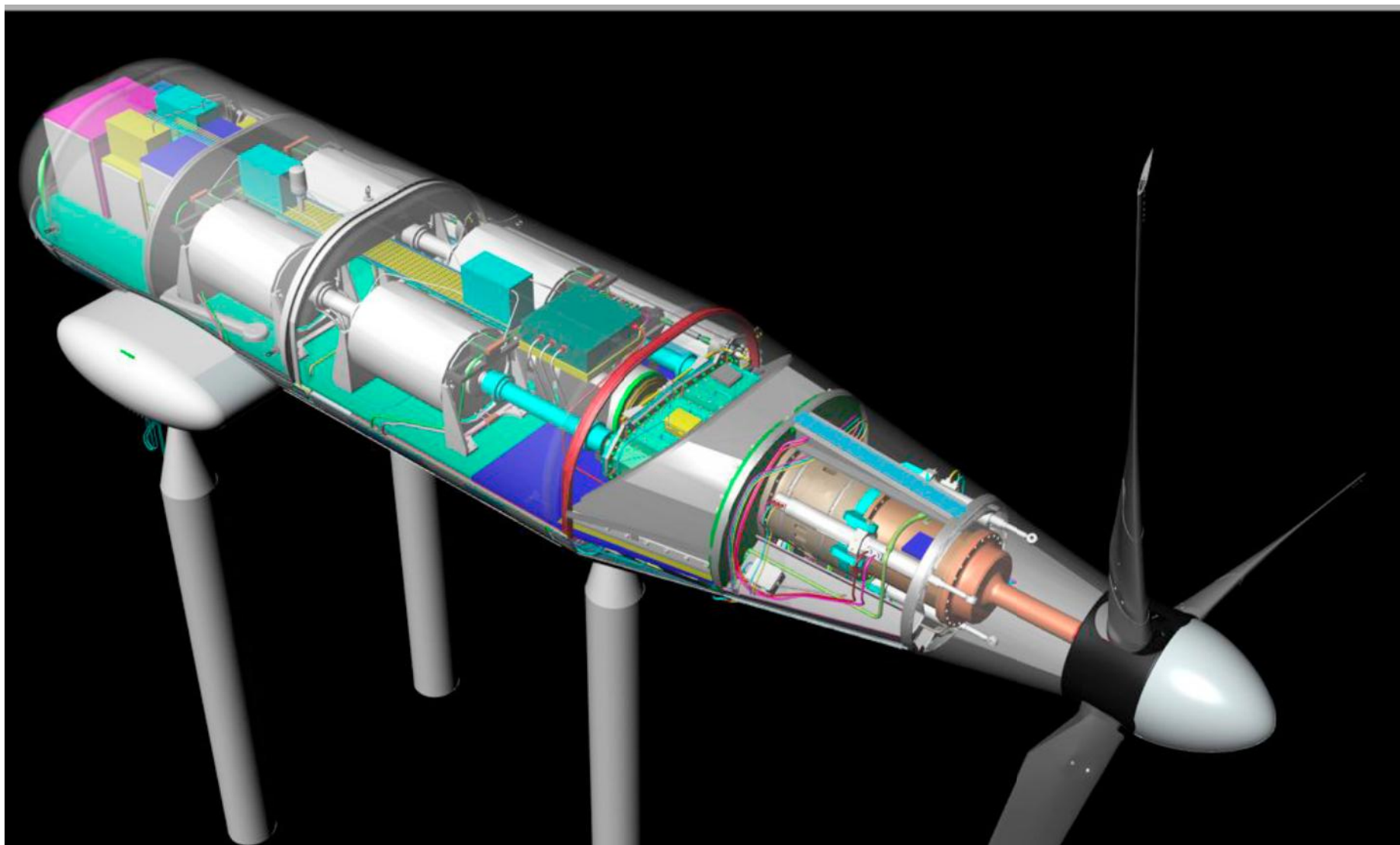
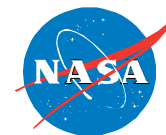
- **Capabilities**

- Rotor Configurations: Proprotor and Edgewise Rotors
- Maximum Wind Speed: 300 kt axial, 180 kt edgewise
- Maximum Rotor Diameter: 26 ft (NFAC 40'x80' Tunnel)
- Maximum Rotor Thrust: 30,000 lb
- Maximum Power: 6000 HP

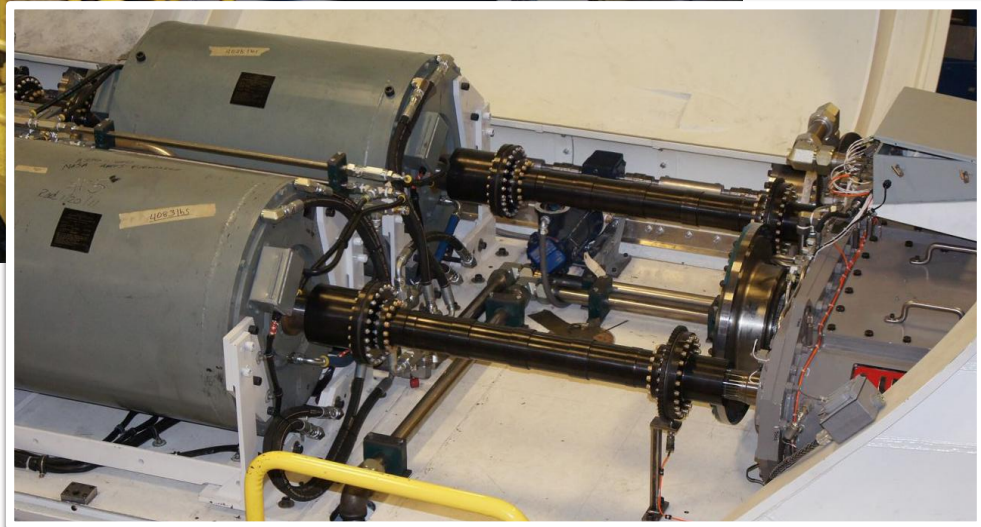
- **Contracts**

- SRW assembled multiple funding sources (SRW base, Recovery Act, Army, Air Force) to support development
- Bell Helicopter contracted to deliver TTR plus 609 hub/blades

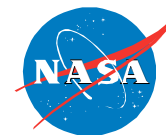
TTR model with 609 rotor



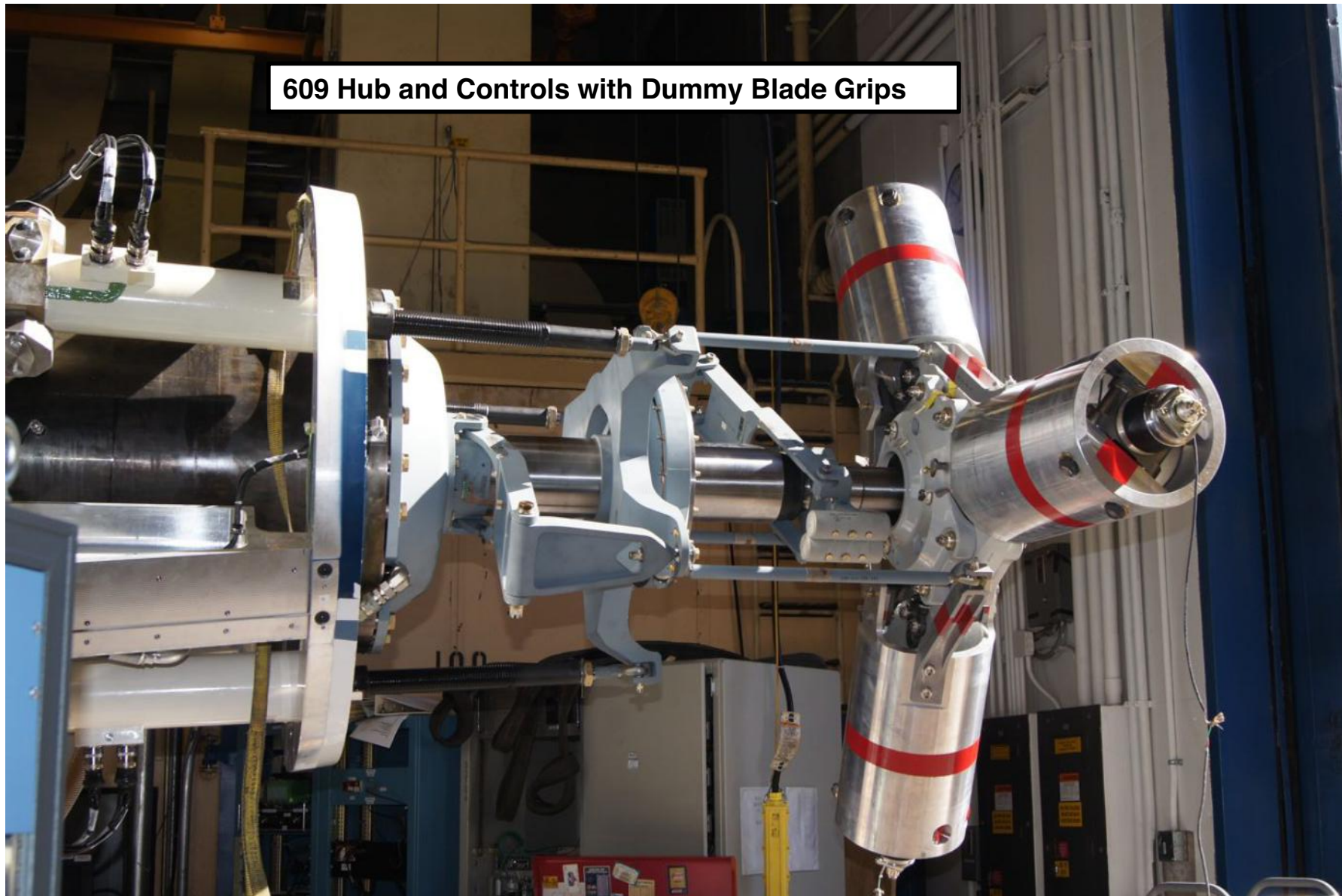
TTR Frame and Fairing



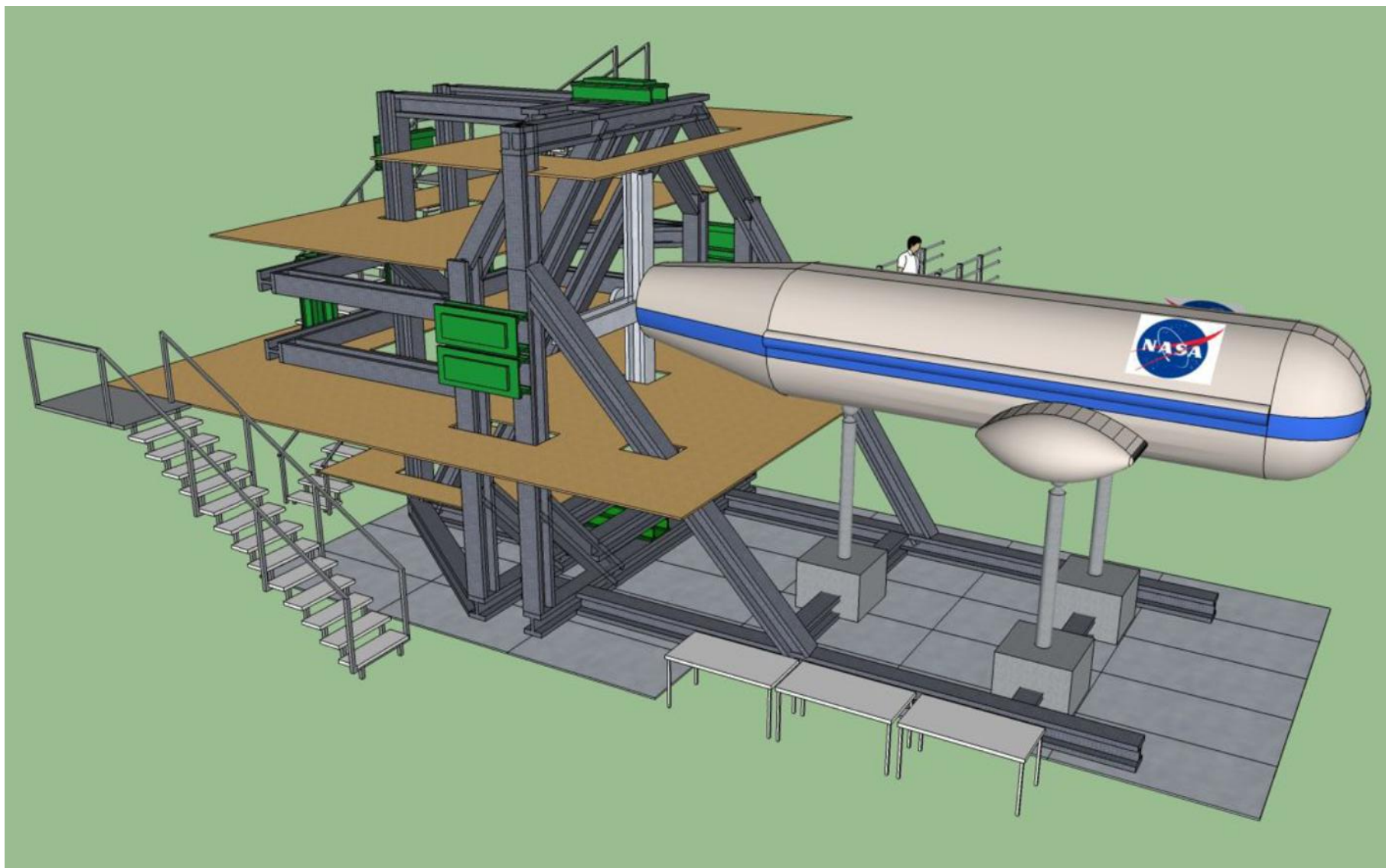
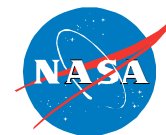
TTR Control System



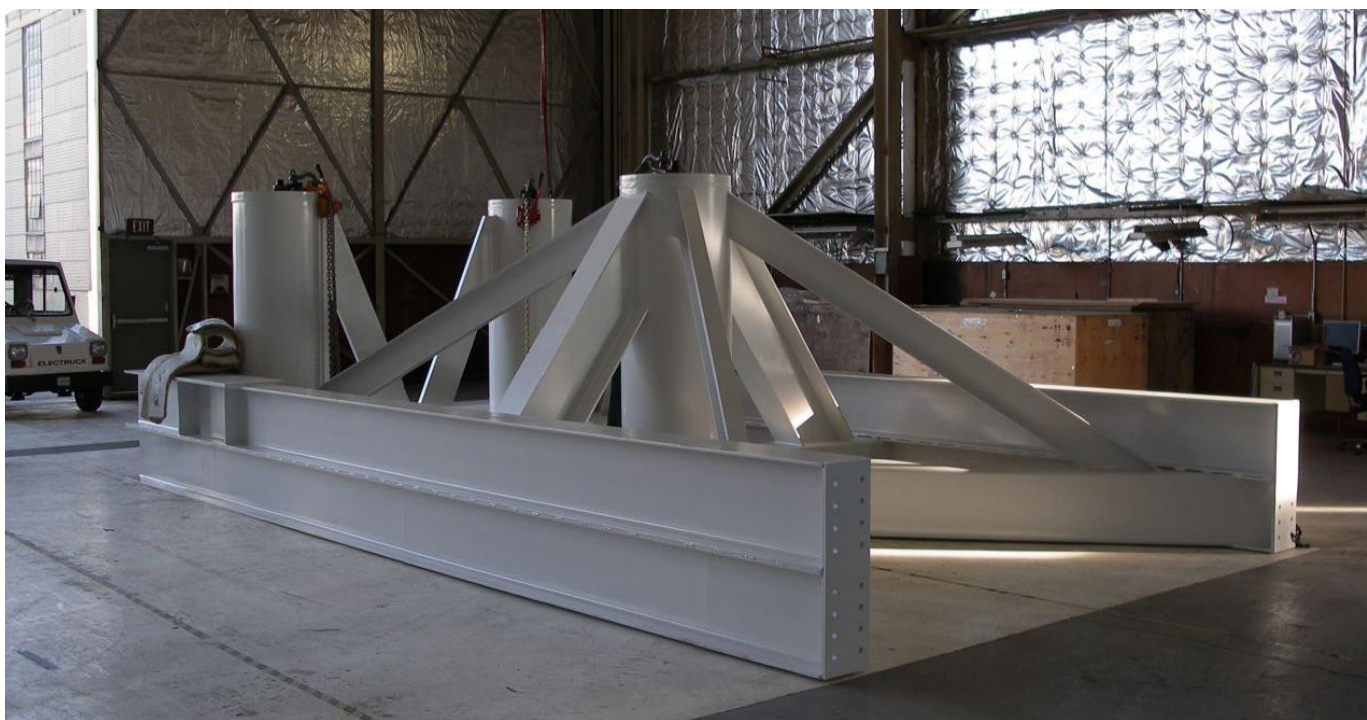
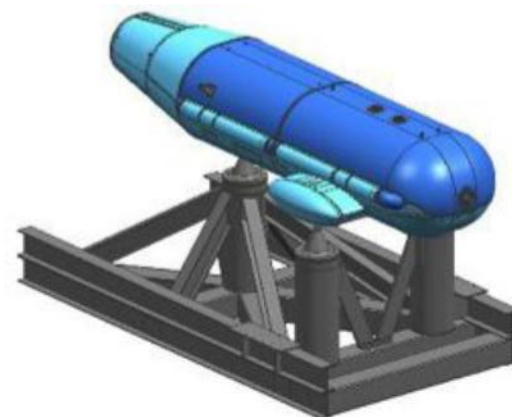
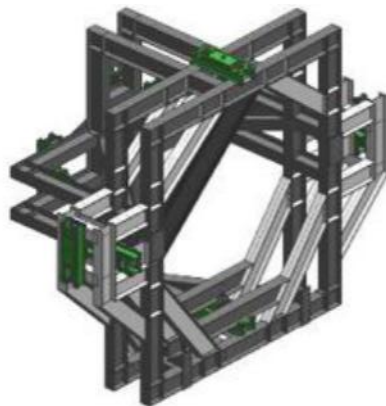
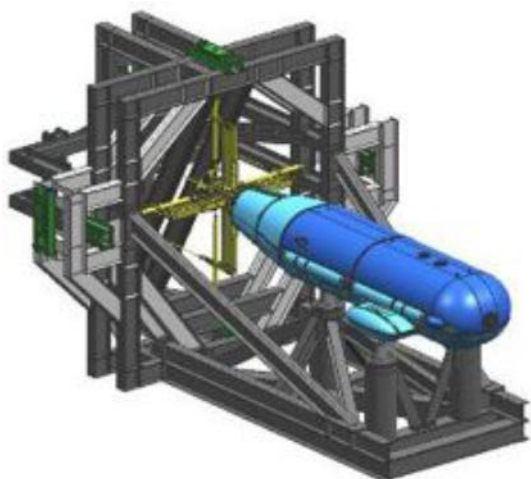
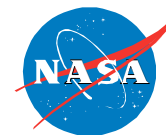
609 Hub and Controls with Dummy Blade Grips



TTR in the Calibration Rig



Calibration Rig Modular Components



TTR Status



- **Accomplishments and Plans**

- TTR fabrication complete and assembly/checkout underway
 - Primary mechanical assembly at Bell complete
 - Hub and actuators installed
 - Functional checkout/control console checkout underway
- NASA model prep building facility mods complete
- TTR calibration rig designed, base frame fabricated and delivered

3/12	Functional and control console checkouts at Bell
4/12	Delivery of TTR test stand and control console
7/12	Delivery of rotor balance and mast module
8/12	TTR drive system checkout at NASA
8/12	Delivery of 609 rotor
11/12	Delivery of final TTR Cal Rig components
CY13	TTR rotor balance calibration
CY14	40x80 Wind Tunnel installation

Rotor in Ground Effect (IGE)



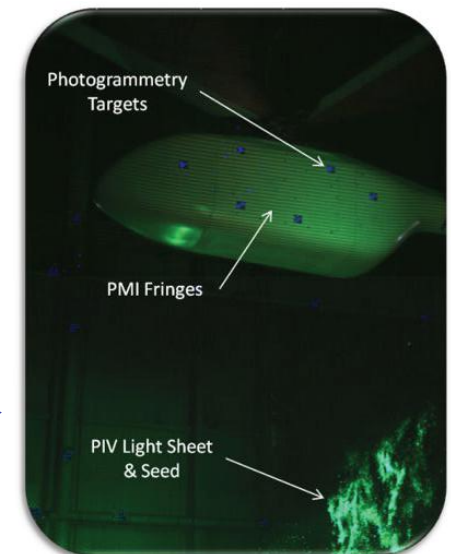
Joint Army/NASA Test Program

Objective

- Characterization of rotor IGE flow field to study phenomenological features and enable improved hover, downwash/outwash and Degraded Visual Environment (DVE) predictions
 - Heavily instrumented with conventional, non-intrusive and developing measurement techniques

Series of three entries

- Entry 1 – focused understanding of facility, test stand and measurement technique limitations (Winter 2011)
 - Utilized fluorescent oil flow visualization, laser-based **single shot** Pressure Sensitive Paint (PSP), Projection Moiré Interferometry (PMI), Particle Image Velocimetry (PIV), Photogrammetry and surface shear stress measurements (S3F)
 - Simultaneous acquisition of PIV or PSP and PMI and Photogrammetry



Ground Plane Flow Field



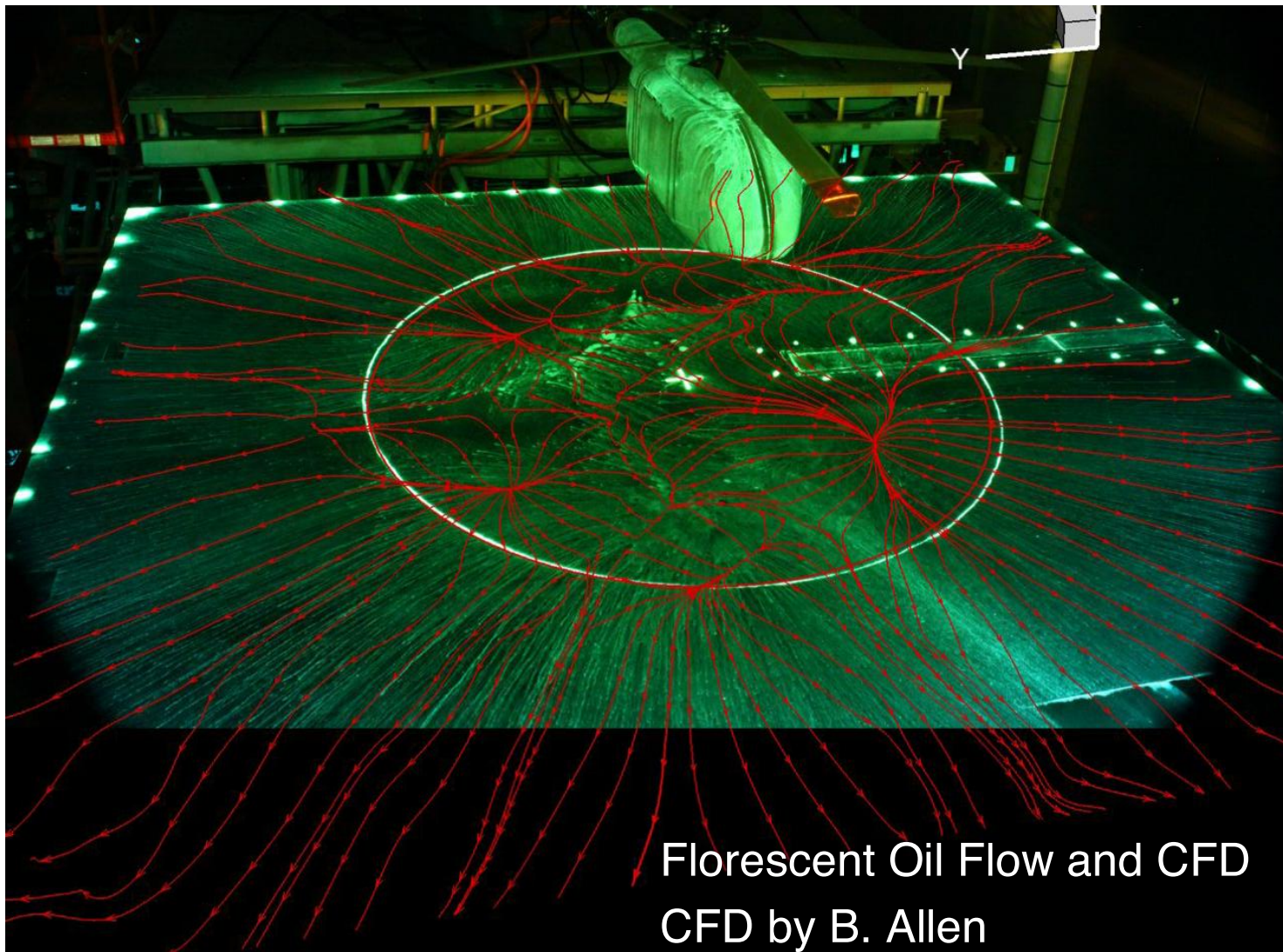
$$h/D = 0.55, C_T = 0.008$$



Ground Plane Flow Field w/ CFD



$$h/D = 0.55, C_T = 0.008$$



Florescent Oil Flow and CFD
CFD by B. Allen

Rotor in Ground Effect (IGE)



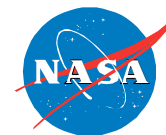
Joint Army/NASA Test Program

Series of three entries (cont)

- Entry 2 – Improved ground plane, parametric variations (Fall 2013)
 - Enlarged, dynamic pressure instrumented ground plane, adjustable in pitch and roll
 - Initiate parametric variation studies: disc loading, number of blades, tip shape, root cutout, ground plane inclination, ground plane roughness
- Entry 3 – Complete parametric variations (Fall 2014)

Plans

- Complete detailed review of the data (Fall 2012)
- Initiate design of enlarged ground plane with tilt capabilities for Entry 2
- Parametric testing with improved ground plane (Entry 2, 2013)



Aeromechanics Near-Term Plans

- Continue development and validation of structured and unstructured rotorcraft CFD methods
- Conduct Active Twist Rotor test in TDT
- Conduct icing test of sub-scale rotor in IRT
- Complete fabrication and development of TTR and conduct checkout test in 40x80
- Continue data evaluation/reduction and analysis validation with data from UH-60 Airloads wind tunnel test
- Complete downwash/outwash test analysis and prepare for follow-on testing
- Evaluate fundamental testing options (new start)
 - Hover performance
 - 2-D oscillating active flap
 - Dynamic stall

