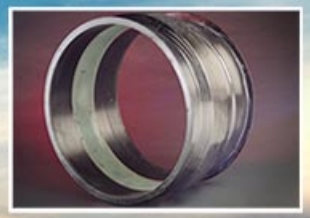
National Aeronautics and Space Administration

Advanced Air Vehicles Program

Revolutionary Vertical Lift Technology Project Overview



Susan A. Gorton, Project Manager

June 25, 2015

www.nasa.gov

Outline

- Civil Market Background
- NASA Vision, Goals
- Project Organization
- Project Technical Challenges
- Example Highlights

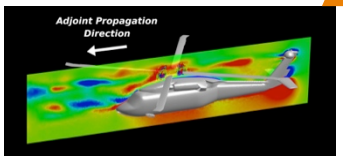
Enhancing Vertical Lift Capabilities

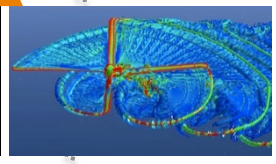
FUTURE CAPABILITIES

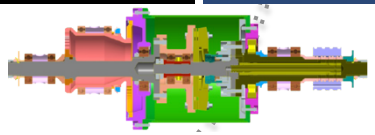
Transformative Concepts

(e.g. hybrid electric, autonomy, new concepts)

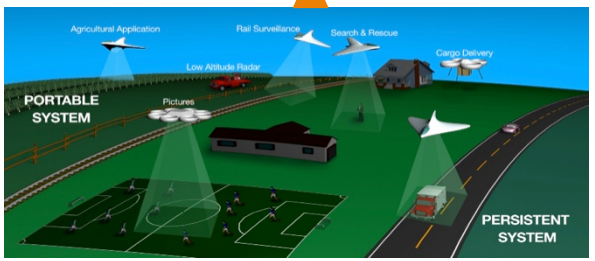
Research focus in Subsonic Rotary Wing and Rotary Wing Projects (2006–2014)







Revolutionary Vertical Lift Technology Project (2015+)
Innovative technologies, tools & concepts (e.g. low noise, efficient propulsion, & optimization technologies)

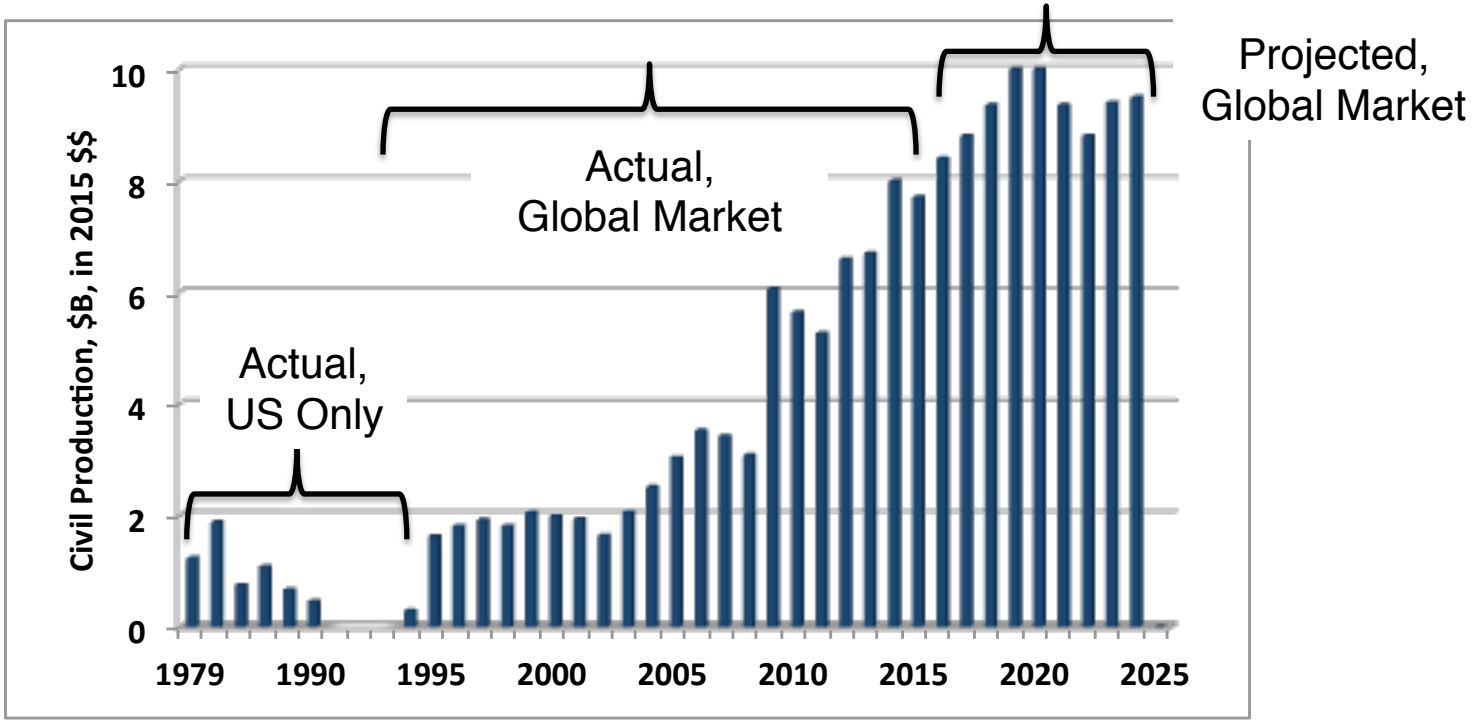


Unmanned Traffic Management System

- Key to safely opening new markets
- Important de-confliction with existing vertical flight

Civil Rotorcraft Market Projections

- Civil Market is projected to continue growth over next decade
  - "Increasing demand for new civil rotorcraft will more than offset the anticipated decline in military demand, with the result being generally rising…at least through 2020."[1]
- Projected growth in new civil production per year:
  - $7.7B in 2015 ⇒ $10.8B in 2020[1]
- Improvement in global deliveries from 10-22% during 2015-2019[2]



[1]The World Rotorcraft Market, Vertiflite, Vol. 61, No. 3, 2015
[2]https:// aerospace.honeywell.com/~/media/infographics/HAI_InfoGraphic_FF_2015_P.ashx?la=en

Civil Rotorcraft Market Descriptions

- Near-term – Projections show civil sector sales increasing while military sales are decreasing; value of production about equal in civil vs military sales by 2020
  - Emergency Medical Service operations in new global markets (particularly India, Korea, China, South America)
  - Oil and gas sector, especially long-range off-shore operations; however, oil price reductions are impacting this market outlook and are being carefully tracked
  - Search & rescue, training, firefighting, law enforcement, surveillance
  - Corporate/executive transport/ tourism

- Long-term – New markets will open 5-20 years
  - Autonomous missions (cargo, pipeline patrol, surveillance, etc.)
  - Urban commuter transport
  - Regional passenger service

- Community noise is the primary barrier to more widespread use of rotary wing vehicles. Performance and affordability are also major barriers.
- Under the Clean Sky Initiatives, the EU has started two major vertical lift initiatives (one helicopter & one tiltrotor).

Envisioned Common Civil Configurations and Missions in 2030 & beyond

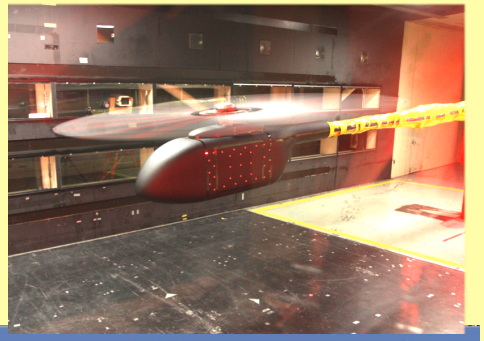
	Configurations				
	Very Light	**Light**	**Medium**	**Heavy**	**UltraHeavy**
Missions	•inspection •photography •filming •spraying •mapping •weather •surveillance •delivery	•police •training •traffic/ news •power line service •spraying •cargo	•police •EMS •traffic/news •tourism •executive •charter •oil platforms •SAR •cargo	•oil platforms •disaster relief •cargo •logging •construction •firefighting •commuter (30 pax)	•commercial transport (90-120 pax) •disaster relief •civil reserve aircraft fleet •cargo
	autonomous capability				
Configura-tions					

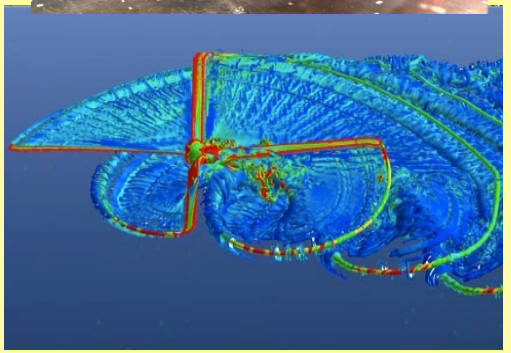
blue highlight: new mission and/or new configuration

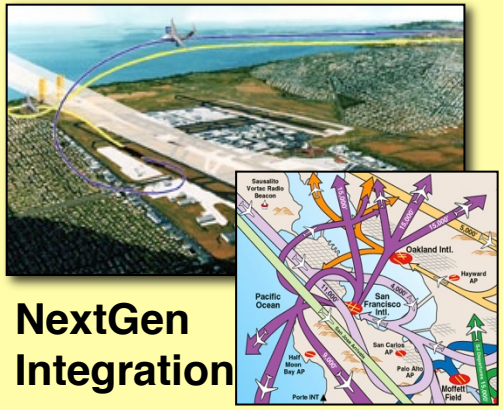
Challenges for Future Vertical Lift Aircraft
(Noise, speed, mobility, payload, efficiency, environment)

Multi-Mission Optimiza-tion

Modeling and Validation

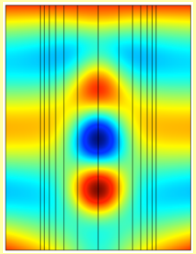




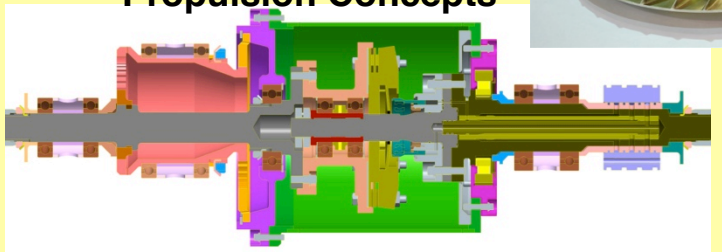


NextGen Integration

Low Noise: External and Internal



Efficient Engines and Drive Systems; New Propulsion Concepts



Revolutionary Vertical Lift Technology (RVLT)

Develop and Validate Tools, Technologies and Concepts to Overcome Key Barriers for Vertical Lift Vehicles

Vision

- Enable generation of vertical lift vehicles with aggressive goals for efficiency, noise, and emissions to expand current capabilities and develop new commercial markets

Scope

- Conventional and non-conventional very light, light, medium, heavy and ultra-heavy vertical lift configurations
- Technologies that address noise, performance, efficiency, safety, community acceptance and affordability

NASA Vertical Lift Project Research Areas

Ames Research Center

- Aeromechanics
- Computational Methods
- Flt Dyn & Ctrl
- Experimental Capability
- System Analysis
- Autonomy

Glenn Research Center

- Drive Systems
- Engines
- Hybrid Electric Systems
- Icing
- System Analysis
- Condition Based Maintenance

Langley Research Center

- Acoustics
- Aeromechanics
- Experimental Capability
- Computational Methods
- Crashworthiness
- Autonomy

- *Typical NASA research is TRL 1-5, sometimes 6*
- *Typical NASA products are feasibility studies, technology demonstrations, research reports*
- *Partnerships enable faster technology transition to DoD and industry*

Resources and Facilities

FY15 RVLT Summary

~65 Civil Service Workforce

~ $20M per year (includes salary)

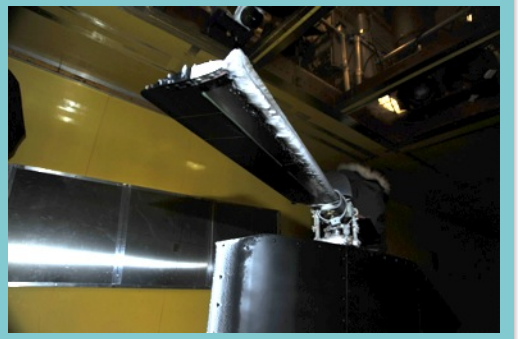
Anticipate similar level of funding for FY16-20

Ames Research Center

- National Full-Scale Aerodynamics Complex (NFAC)
- Supercomputing Complex (NAS)
- Vertical Motion Simulator

Glenn Research Center

- Compressor Test Facility (CE-18)
- Transonic Turbine Blade Cascade Facility (CW-22)
- Transmission Test Facilities (ERB)
- Icing Research Tunnel



Langley Research Center

- 14- by 22-Foot Subsonic Tunnel
- Transonic Dynamics Tunnel
- Landing and Impact Research
- Exterior Effects Synthesis & Sim Lab
- Mobile Acoustic Facility

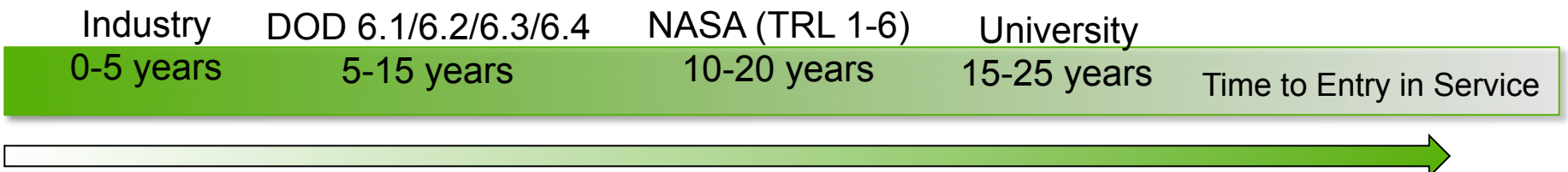
Technical Challenge Selection

Tech Challenge selection based on:

- NASA SME knowledge and input on future rotorcraft needs
- System studies for advanced rotorcraft concepts, 2005-2013, performed by NASA, DoD and Industry in support of various NASA and DoD requirements
- System studies of benefits of technology concepts sponsored by NASA and performed by industry
- NASA has critical mass to make significant contributions

Selection informed by and aligned with:

- NASA Aeronautics Strategic Implementation Plan
- National Aeronautics R&D Plan
- NRC Decadal Survey
- Feedback from OGA and Industry



RVLT Research Themes & Tech Challenges

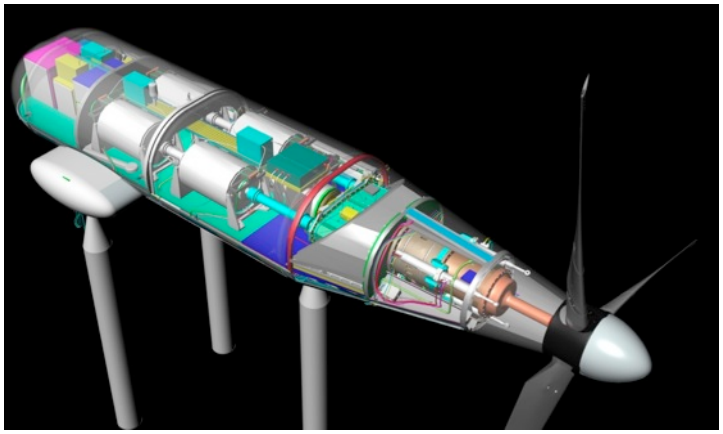
Research Themes	Technical Challenges 2015-2020	Other Research in Theme Area 2015-2020
Advanced Efficient Multi-speed Propulsion	**Variable Speed Power Turbine Technology Demo:** Demonstrate 50% improvement in efficient operational capability **Two-Speed Drive System Demo:** Demonstrate two-speed drive system with 50% rpm reduction	• High efficiency gas generators • Hybrid electric propulsion • Condition Based Maintenance methods
Low-Noise Vertical-Lift Concepts and Configurations	**NEW Technical Challenge: Demonstration of an MDAO Design Process for Vertical Lift Vehicles (draft)** **NEW Technical Challenge: Design Capability for a Low-Noise Rotor Considering Constraints (draft)** .	• Internal cabin noise • Crashworthiness • Icing for rotorcraft • Hover performance and prediction • High fidelity CFD modeling and accuracy for advanced configurations

NASA RVLT Project Areas of Investment, FY15-17

Multi-Speed Propulsion

Variable-Speed Turboshaft Engines
- Variable-speed power turbine
- High-efficiency gas generators

Multi-Speed Lightweight Drive Systems
- Advanced gearbox components and configurations
- Variable-speed transmission
- Condition based maintenance



Tiltrotor Test Rig drive system schematic

Multi-Disciplinary Design, Analysis, and Optimization

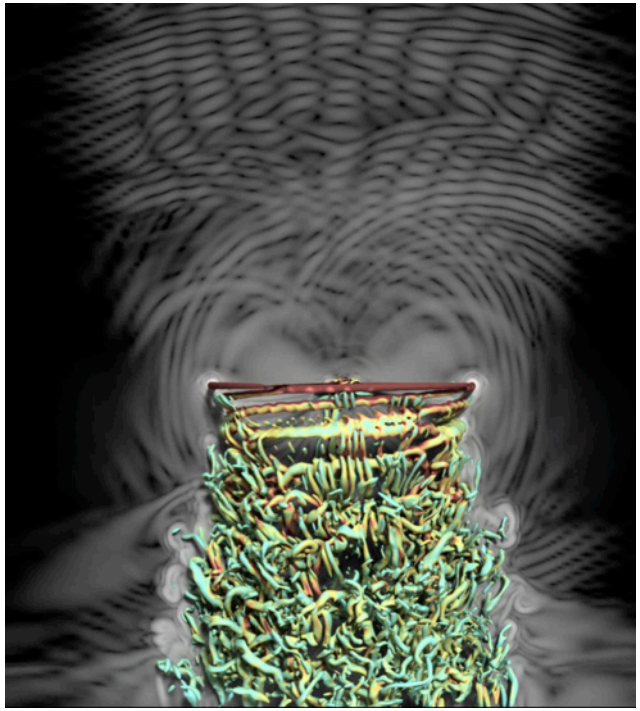
Validated Multi-Disciplinary Design Tools
- High-fidelity modeling
- Experimental validation and methods

Optimization Process for Conceptual Design
- OpenMDAO framework
- Conceptual design and sizing tools

Safe and Certifiable VTOL Configurations

Low Noise Optimized Rotor
- Acoustics
- Aeromechanics and Rotor Performance

Safety and Environment
- Impact Dynamics
- Community Noise and Response
- Icing



High-resolution hover calculation.

RVLT Research Approach

Three main paths to accomplish research:

- NASA in-house research
- Research with partners (Other Government Agencies, Industry, Universities)
- Sponsored research proposals through NASA Research Announcement (NRA); SBIR; other contracts

Glenn Research Center

NASA AMES Platinum Jubilee

NASA Langley 90th Anniversary

U.S.ARMY

DARPA

Department of the Navy, United States of America

A&P Technology

Pratt & Whitney

Sikorsky

Cobham

Launchpoint

UTRC

FAA

Boeing

Bell

ES Aero

CDI

ONERA

DLR

NLR

GE

MTI

Sukra

Helitek

ISSI

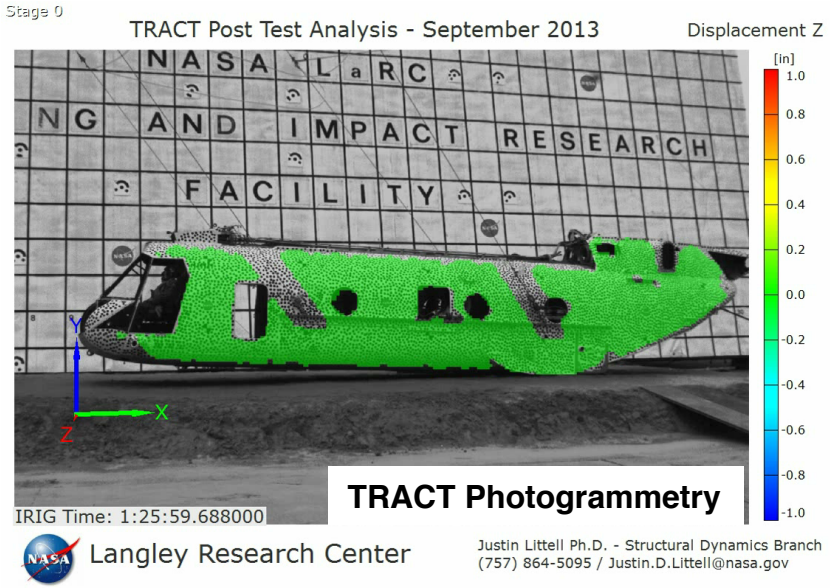
Georgia Tech

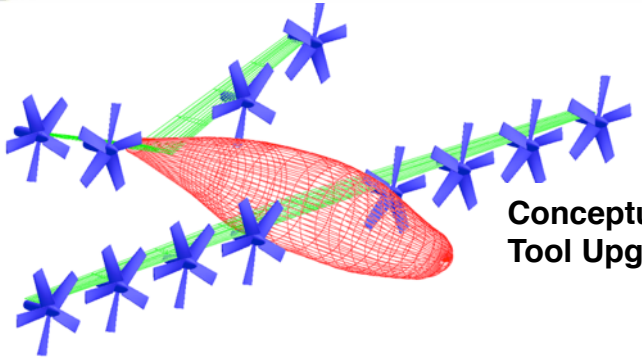
Penn State 1855

University of Maryland 1856

Highlights of Recent Research Activities

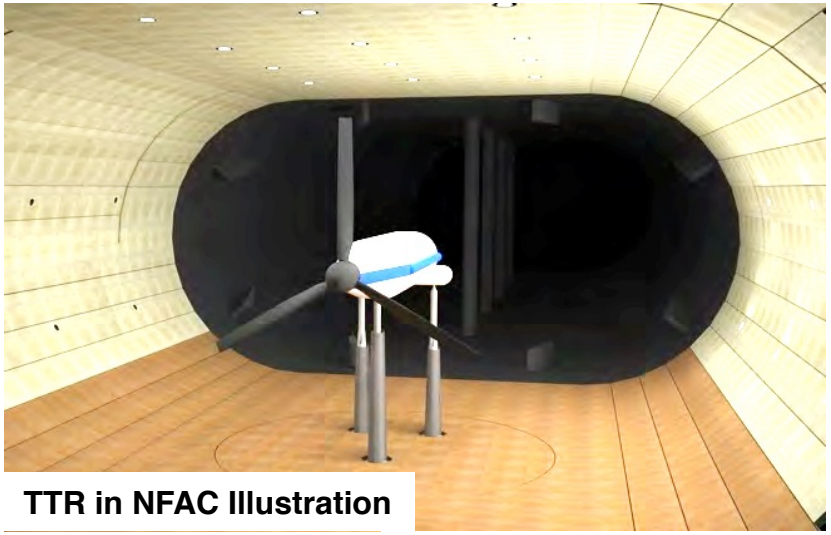
- **TRACT** test team completes second phase of impact and human occupant/ seat restraint testing
- **Two-Speed Transmission Demo** 50% rpm shift under full rpm for two transmission concepts
- **Conceptual Design** tool upgrades for electric/hybrid electric propulsion complete
- **Advanced compressor report published** CR 2014-218114: “High Efficiency Centrifugal Compressor for Rotorcraft Applications”
- **FUN3D team** demonstrates implementation of unsteady adjoint for overset meshes and improved accuracy of calculations by 37%
- **OVERFLOW team** demonstrates adaptive mesh refinement and accuracy improvements within experimental error





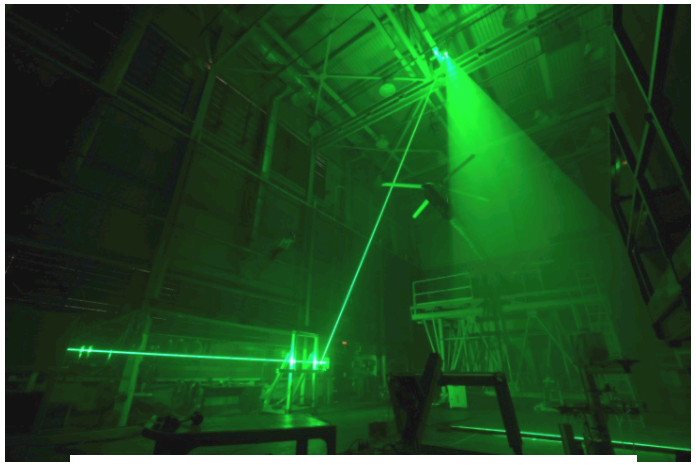
Highlights of Recent Research Activities

- **Advanced measurement technique development** Large Field PIV, Unsteady PSP, IR Thermography, Photogrammetry continue to improve in accuracy and efficiency
- **Active Flow Control** on oscillating airfoil demonstrates effectiveness to M=0.4

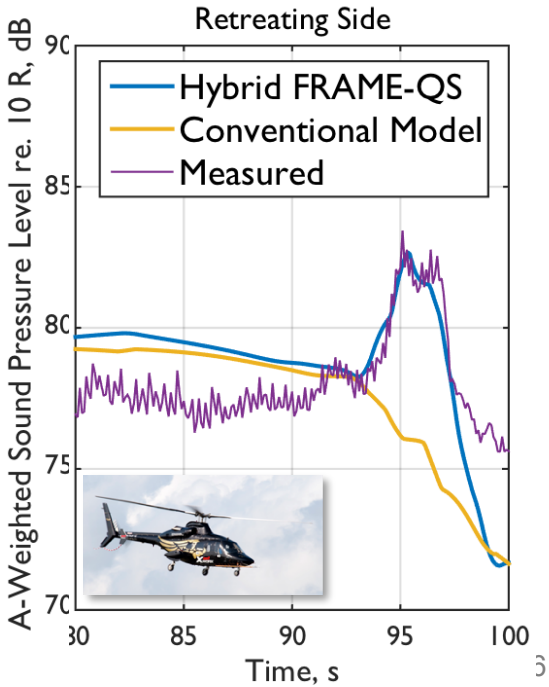


TTR in NFAC Illustration

- **Acoustic maneuver and altitude flight testing completed** FRAME calculations matching maneuver measurements
- **Tiltrotor Test Rig balance calibration complete** Functional checkout scheduled in NFAC in FY16

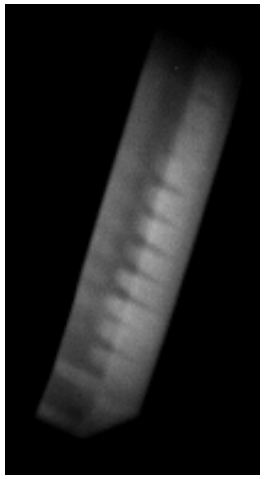


Advanced Measurements in Hover

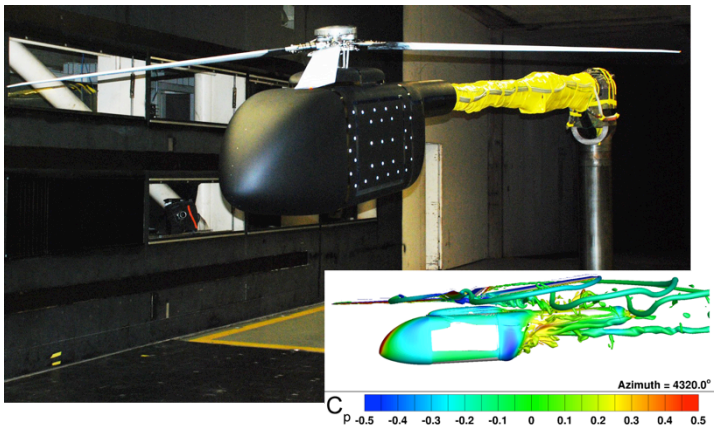


Summary

- NASA RVLT is focused on overcoming significant barriers to the use of vertical lift vehicles in expanded missions
- Providing technology leadership
  - Technologies to optimize rotor designs for low noise considering other operational constraints
  - Efficient configuration concepts that reduce fuel burn
  - Technologies aimed at low/no greenhouse gas emission
  - Technologies that improve affordability
- Develop vision of the future for vertical lift
  - Determine feasibility for advanced innovative concepts

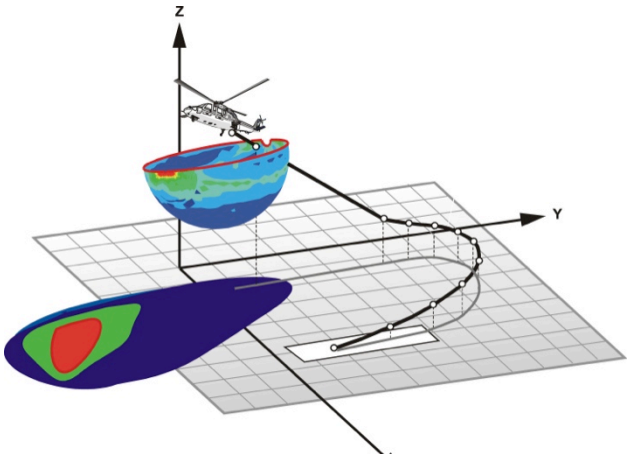


Thermal imaging of transition on rotor blade

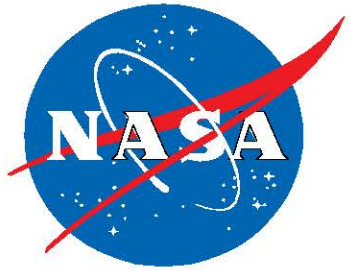


Fuselage drag reduction

Conceptual design



Noise Modeling


NASA