NASA Overview: Revolutionary Vertical Lift Technology Project Research and Goals

Presented to Aeronautics and Space Engineering Board (ASEB)

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Outline

- Historical NASA civil rotorcraft system studies
- Current market outlook
- Integrated ARMD vertical lift strategy
- Revolutionary Vertical Lift Technology (RVLT) project
- RVLT Technical Challenge focus
- RVLT partnerships and agreements
- Working with the DoD
- Summary

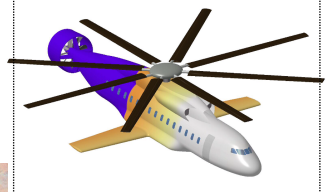
Civil Rotorcraft: Past Major Studies

1987-1991: Civil Tiltrotor Missions and Applications: Phase I & II (Boeing, Bell, Boeing Vertol, NASA)

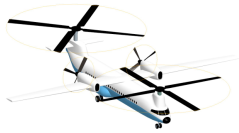
1995: Report to Congress: Civil Tiltrotor Development, Vol. I & II

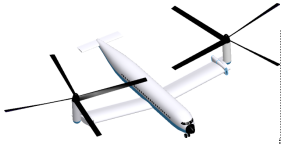
1993-2001: NASA Short-Haul Civil Tiltrotor Concepts

2000-2003: Runway Independent Aircraft Studies (Bell, Boeing, Sikorsky; NASA funded)



2004-2005: NASA Heavy-Lift Rotorcraft Systems Investigation

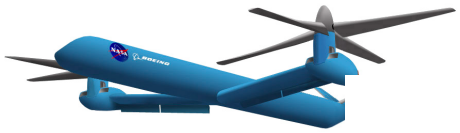


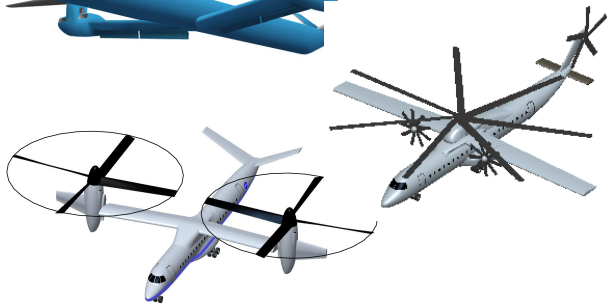


2009-2011: Modeling High-Speed Civil Tiltrotor Transports in the Next Generation Airspace (SAIC et al; NASA funded)

2009: Advanced Vehicle Concepts and Implications for NextGen (Sensis et al; NASA funded)

2009: Aircraft System Analysis of Technology Benefits to Civil Transport Rotorcraft (Boeing; NASA funded)





Base R&T	Short-Haul Civil Tiltrotor / Aviation Systems Capacity		Vehicle Systems	Fundamental Aero
• 8-75 pax • 270-300 kts	• 40 pax • 315 kts	• 80, 90, 120 pax • 310-350 kts	• 120 pax • 350 kts	• 30-120 pax • 250-350 kts

Civil Rotorcraft Market Current Outlook

- Civil Market is projected to continue growth over next decade[1]
  - $7.7B in 2015 ⇒ $10.8B in 2020[1]
  - Improvement in global deliveries from 10-22% during 2015-2019[2]
- 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 – Possible new markets will open 5-20 years
  - Autonomous missions (cargo, pipeline patrol, surveillance, etc.)
  - Urban commuter transport
  - Regional passenger service

[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

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

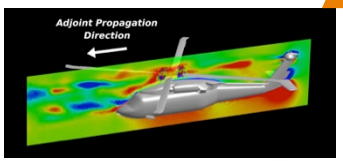
Enhancing Vertical Lift Capabilities

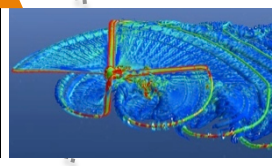
FUTURE CAPABILITIES

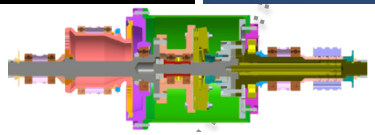
Transformative Concepts

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

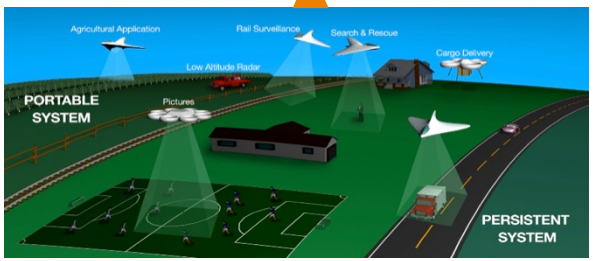
Research focus in Subsonic Rotary Wing and Rotary Wing Projects (2006–2014)







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

Ultra-Efficient Commercial Vehicles, Vertical Lift

Roadmaps for each of the six Thrusts in the Strategic Implementation Plan are being developed

- **Creates an opportunity to update the SIP Outcomes and set direction for research areas**
- **Current working draft of the roadmap and Outcomes highlights the potential for vertical lift vehicles in many new roles and markets**

DRAFT Outcomes:

Increased capability of vertical lift configurations foster economic and mobility benefits for new and current market

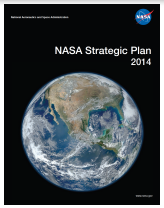
New vertical lift configurations and technologies introduced that enable new markets, increase mobility and provide accessibility

Vertical lift vehicles of all sizes used for transportation, providing services, mobility, accessibility, economic benefits and environmental sustainability

DRAFT New Research Themes: Clean and Efficient Propulsion; Efficient and Quiet Vehicles; Safety, Comfort, Accessibility; ModSim and Test Capability

Note: Outcomes and Themes are not dependent on vehicle size; inclusive of small to large configurations

Guidance for Vertical Lift Portfolio



NASA Strategic Plan
"Advance aeronautics research for societal benefit"

National Aeronautics R&D Plan

NRC 2006 Decadal Survey of Civil Aeronautics

ARMD Strategic Thrusts
- Ultra-Efficient Commercial Vehicles
- Transition to Low-Carbon Propulsion
- Assured Autonomy for Aviation Transformation

Feedback and Ideas:
- OGA partners
- Industry and University
- NASA internal

U.S.ARMY

FEDERAL AVIATION ADMINISTRATION

Noise, speed, mobility, payload, efficiency, environment, safety

Revolutionary Vertical Lift Technology Technical Challenges and Portfolio Investment

Dependencies/leveraging
- Advanced Air Transport Technology (hybrid electric propulsion technology)
- Airspace Operations and Safety Program (Umanned Aerial Systems Traffic Management)
- Transformative Aeronautics Concepts Program (cross-cutting technology)

Revolutionary Vertical Lift Technology Project

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

Vision

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

Scope

- *Technologies that address noise, speed, mobility, payload, efficiency, environment, safety*
- *Conventional and non-conventional very light, light, medium, heavy and ultra-heavy vertical lift configurations*

RVLT Research Themes & Tech Challenges

Area of Emphasis (Research Themes)	Technical Challenges 2015-2020	Other Research in Theme Area 2015-2020	Addresses
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	Speed, mobility, efficiency, environment, payload, noise, safety
Low-Noise Vertical-Lift Concepts and Configurations	**Technical Challenge: Demonstration of an MDAO Design Process for Vertical Lift Vehicles (draft)** **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	Noise, speed, mobility, efficiency, safety, environment, payload

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)

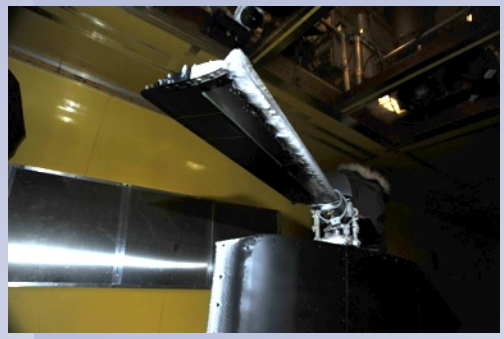
Anticipate similar level of funding for FY16-20

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

Collaboration with DOD

NASA/Army MOU for Collaborative Joint Research

- Co-located Army research laboratories at NASA Ames, Glenn and Langley
- 50 years of joint research for rotary wing technologies
- Performance, speed, payload, efficiency, and noise improvements support civil and military current and future requirements

Participate in Future Vertical Lift and JMR

- Mr. Dryer sits on FVL Executive Steering Committee
- Ms. Gorton is member of the FVL Science and Technology Overarching Integrated Product Team; provide roadmaps between NASA and DoD for technology development; identify gaps
- Support development of S&T Roadmaps for Platforms, Engines, Operations and Sustainment, Flight Dynamics, Survivability

Jointly fund the Vertical Lift Research Centers of Excellence with Army and Navy

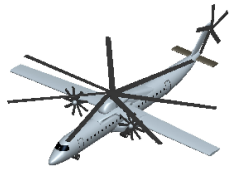
Participate as SME and evaluators for Army, Navy, DARPA programs

NASA performs reimbursable work for the DoD

- When work directly supports a DoD mission with no connection to NASA goals

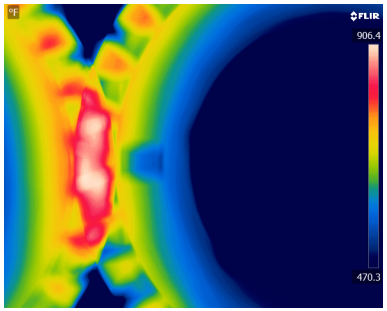




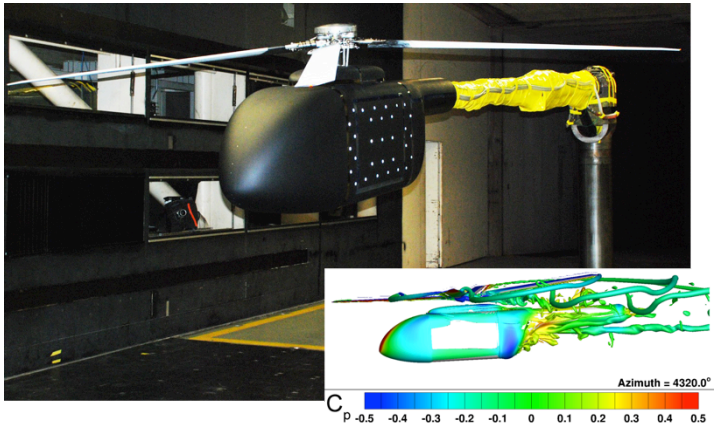


Summary

- 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 noise, speed, mobility, payload, efficiency, environment, safety
- Develop vision of the future for vertical lift
  - Determine feasibility for advanced innovative concepts

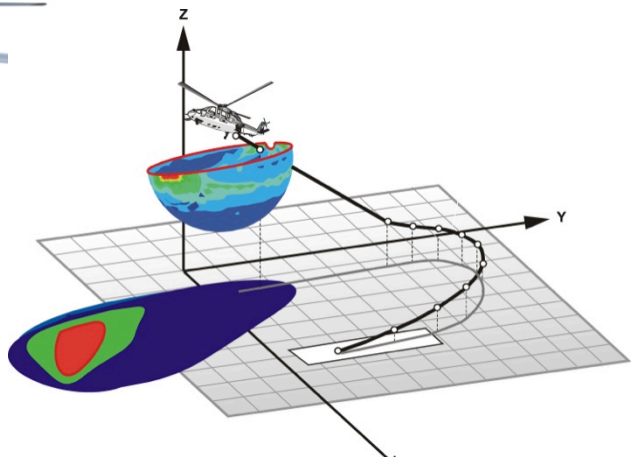


Thermal imaging of gear teeth

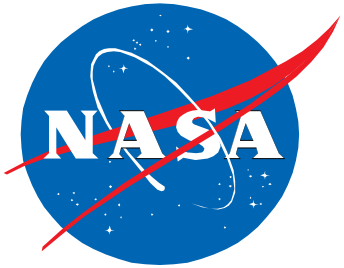


Fuselage drag reduction

Conceptual design



Noise Modeling


NASA

Barriers to Expanded Vertical Lift

- Community acceptance
  - Noise
  - Safety
  - Land Use
- Cost
  - Performance/ efficiency
  - Payload
  - Speed
  - Maintenance
- Regulatory/local ordinances
  - Airspace operations (particularly for UAS)
  - Certification path (particularly for unconventional propulsion)
  - Time/Cost to certify

What is the Rest of the World Doing?

- UAS – depends on locality, but relaxed or non-existent restrictions on operations
- EU has launched Clean Sky II, has fast rotorcraft component[1]
  - LifeRCraft compound helicopter
  - NextGenCTR tilt-rotor
  - Focus on environmental technologies
- Russia Helicopters is gaining ground in export market
- Airbus Helicopters investing in South America, Asia
- China, Korea, India investing in indigenous capability

[1]http://cleansky.eu/content/page/fast-rotorcraft

ARMD Programs/Projects With Possible Application to Vertical Lift

Airspace Operations and Safety Program

- Airspace Technology Demonstrations
- Shadow Mode Assessment in NAS
- Safe Autonomous Systems Ops
- UAS Traffic Management

Advanced Air Vehicles Program

- Aeronautics Evaluation and Test Capabilities
- Advanced Air Transport Technology
- Advanced Composites
- Commercial Supersonic Technology
- Revolutionary Vertical Lift Technology

Integrated Aviation Systems Program

- Environmentally Responsible Aviation
- UAS in the National Airspace System
- Flight Demonstrations and Capabilities

Transformative Aeronautics Concepts Program

- Convergent Aeronautics Solutions
- Transformative Tools and Technologies
- Leading Edge Aero Research for NASA (LEARN)

Partnerships and Collaborations

Key Partnerships

Vertical Lift Research Centers of Excellence (VLRCOE) SAA through FY15

- Army ADD/AFDD
- Office of Naval Research (ONR)

Army and Vertical Lift Consortium (Icing research, Airloads workshop)

Naval Research Laboratory

Smart Twisting Active Rotor (STAR) International partnerships (DLR, ONERA, JAXA, Korea, US)

Pratt and Whitney

General Electric

Joby Aviation

United Technologies Research Center

Bell Helicopter

PSU-ARL

A&P Technologies

Key Agreements

NASA-Army MOU for Collaborative Research in Aeronautics, August 2007

- Army Aeroflightdynamics Directorate (ADD/AFDD)
- Army Research Laboratory, Vehicle Technology Directorate (ARL-VTD)
- Army Applied Aviation Technology Directorate ADD/(AATD)
- PEO Aviation Cargo Helicopters (Redstone Arsenal)

French MOA – Fuselage Drag Reduction (ended FY14), Green Metrics for Rotorcraft (ended FY15)
(tasks under US Army/French MOD Project Agreement, PA)

German DLR Framework: collaboration on TRACT2 test (ended FY15); rotor experimental optical methods

NLR LOA—aircraft flyover noise

Recent SBIR Activities

Title/ Performer	Year/Phase
Small VTOL UAV Acoustics Measurement and Prediction, Continuum Dynamics, Inc., 14-1-A3.06-9430 LaRC	2014 Phase 1
Validated Design and Analysis Tools for Small Vertical-Lift Unmanned Air Vehicle Noise Prediction, Delta Group International, LLC., 14-1-A3.06-8620 LaRC	2014 Phase 1
Hybrid-Electric and All-Electric Rotorcraft Analysis and Tool Development, Empirical Systems Aerospace, Inc., 14-1-A3.06-9367 ARC	2014 Phase 1
Hybrid Electric Propulsion System for a 4 Passenger VTOL Aircraft, LaunchPoint Technologies, Inc., 14-1-A3.06-9495 GRC	2014 Phase 1
A Computational Tool for High Advance Ratio Configurations, Sukra Helitech, Inc., 14-1-A3.06-8898	2014 Phase 1
Adaptive Liners for Broadband Noise Reduction, Cornerstone Research Group, Inc., A3.02-9830	2014 Phase 2
Hybrid-Electric Rotorcraft Tool Development, Propulsion System Trade Space Exploration, and Demonstrator Conceptual Design, Empirical Systems Aerospace, Inc., A3.06-9367	2014 Phase 2
Hybrid Electric Propulsion System for a VTOL/Multirotor Aircraft, LaunchPoint Technologies, Inc., A3.06-9495	2014 Phase 2
High Fidelity Prediction and Experiment of Small Multi-Rotor VTOL UAVs, Bain Aero LLC, A1.06-9364	2015 Phase 1
Non-Contact Magnetic Transmission For Hybrid/Electric Rotorcraft, LaunchPoint Technologies, Inc., A1.06-9338	2015 Phase 1
Vertical Lift by Series Hybrid Power, Aurora Flight Sciences Corporation, A1.06-9851	2015 Phase 1

List of Major Studies

Title	Report Number
The History of the XV-15 Tilt Rotor Research Aircraft	SP-2000-4517
Civil Tiltrotor Missions and Applications Study: Supporting Documentation for U. S. Policy Making Decisions	CR-1987-177451
Civil Tiltrotor Missions and Applications Phase II: The Commercial Passenger Market Final Report Book Two: Sections Four and Five	CR-1991-177576
Civil Tiltrotor Missions and Applications, Phase II: The Commercial Passenger Market Final Report Supporting Documentation for U. S. Policy Making Decisions	CR-1991-177591
Civil Tiltrotor Development Advisory Civil Tiltrotor Development Committee Report to Congress, Advisory Committee Volume 1, Final Report	1995
Civil Tiltrotor Development Advisory Civil Tiltrotor Development Committee Report to Congress, Advisory Committee Volume 2, Technical Supplement	1995
The ASAC Flight Segment Aviation and Network Cost Models	CR-1997-201679
XV-15 Low-Noise Terminal Area Operations Testing	CR-1998-206946
Air Cargo Operations Cost Database	CR-1998-207655
The Aviation System Analysis Capability Airport Capacity and Delay Models	CR-1998-207659
Key Metrics and Goals for NASA's Advanced Air Transportation Technologies Program	CR-1998-207678
A Method for Forecasting the Commercial Air Traffic Schedule in the Future	CR-1999-208987
NASA Heavy Lift Rotorcraft Systems Investigation	TP–2005-213467
Modeling High-Speed Civil Tiltrotor Transports in the Next Generation Airspace	CR-2011-215960
An Assessment of Civil Tiltrotor Concept of Operations in the Next Generation Air Transportation System	CR-2012-215999