NASA Overview: Revolutionary Vertical Lift Technology Project Research and Goals

Presented to Aeronautics and Space Engineering Board (ASEB)

Susan A. Gorton
Project Manager

October 21, 2015

www.nasa.gov
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)


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

- 8-75 pax
- 270-300 kts

Short-Haul Civil Tiltrotor / Aviation Systems Capacity

- 40 pax
- 315 kts

- 80, 90, 120 pax
- 310-350 kts

- 120 pax
- 350 kts

- 30-120 pax
- 250-350 kts

Vehicle Systems

Fundamental Aero
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

<table>
<thead>
<tr>
<th>Missions</th>
<th>Very Light</th>
<th>Light</th>
<th>Medium</th>
<th>Heavy</th>
<th>UltraHeavy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• inspection • photography • filming • spraying • mapping • weather • surveillance • delivery</td>
<td>• police • training • traffic/news • power line service • spraying • cargo</td>
<td>• police • EMS • traffic/news • tourism • executive • charter • oil platforms • SAR • cargo</td>
<td>• oil platforms • disaster relief • cargo • logging • construction • firefighting • commuter (30 pax)</td>
<td>• commercial transport (90-120 pax) • disaster relief • civil reserve aircraft fleet • cargo</td>
</tr>
</tbody>
</table>

autonomous capability

### Configurations

- [Image of various aircraft configurations]  

*blue highlight: new mission and/or new configuration*
Enhancing Vertical Lift 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

FUTURE CAPABILITIES
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:**

<table>
<thead>
<tr>
<th>2015</th>
<th>2025</th>
<th>2035</th>
</tr>
</thead>
</table>

- 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

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

NRC 2006 Decadal Survey of Civil Aeronautics

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 (Unmanned 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

<table>
<thead>
<tr>
<th>Area of Emphasis (Research Themes)</th>
<th>Technical Challenges 2015-2020</th>
<th>Other Research in Theme Area 2015-2020</th>
<th>Addresses</th>
</tr>
</thead>
</table>
| 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
**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
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
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 (VLR COE) 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

<table>
<thead>
<tr>
<th>Title/ Performer</th>
<th>Year/Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small VTOL UAV Acoustics Measurement and Prediction, Continuum Dynamics, Inc., 14-1-A3.06-9430 LaRC</td>
<td>2014 Phase 1</td>
</tr>
<tr>
<td>Hybrid-Electric and All-Electric Rotorcraft Analysis and Tool Development, Empirical Systems Aerospace, Inc., 14-1-A3.06-9367 ARC</td>
<td>2014 Phase 1</td>
</tr>
<tr>
<td>Hybrid Electric Propulsion System for a 4 Passenger VTOL Aircraft, LaunchPoint Technologies, Inc., 14-1-A3.06-9495 GRC</td>
<td>2014 Phase 1</td>
</tr>
<tr>
<td>A Computational Tool for High Advance Ratio Configurations, Sukra Helitech, Inc., 14-1-A3.06-8898</td>
<td>2014 Phase 1</td>
</tr>
<tr>
<td>Adaptive Liners for Broadband Noise Reduction, Cornerstone Research Group, Inc., A3.02-9830</td>
<td>2014 Phase 2</td>
</tr>
<tr>
<td>Hybrid Electric Propulsion System for a VTOL/Multirotor Aircraft, LaunchPoint Technologies, Inc., A3.06-9495</td>
<td>2014 Phase 2</td>
</tr>
<tr>
<td>High Fidelity Prediction and Experiment of Small Multi-Rotor VTOL UAVs, Bain Aero LLC, A1.06-9364</td>
<td>2015 Phase 1</td>
</tr>
<tr>
<td>Non-Contact Magnetic Transmission For Hybrid/Electric Rotorcraft, LaunchPoint Technologies, Inc., A1.06-9338</td>
<td>2015 Phase 1</td>
</tr>
<tr>
<td>Vertical Lift by Series Hybrid Power, Aurora Flight Sciences Corporation, A1.06-9851</td>
<td>2015 Phase 1</td>
</tr>
</tbody>
</table>
## List of Major Studies

<table>
<thead>
<tr>
<th>Title</th>
<th>Report Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>The History of the XV-15 Tilt Rotor Research Aircraft</td>
<td>SP-2000-4517</td>
</tr>
<tr>
<td>Civil Tiltrotor Development Advisory Civil Tiltrotor Development Committee Report to Congress, Advisory Committee Volume 1, Final Report</td>
<td>1995</td>
</tr>
<tr>
<td>Civil Tiltrotor Development Advisory Civil Tiltrotor Development Committee Report to Congress, Advisory Committee Volume 2, Technical Supplement</td>
<td>1995</td>
</tr>
<tr>
<td>The ASAC Flight Segment Aviation and Network Cost Models</td>
<td>CR-1997-201679</td>
</tr>
<tr>
<td>Air Cargo Operations Cost Database</td>
<td>CR-1998-207655</td>
</tr>
<tr>
<td>The Aviation System Analysis Capability Airport Capacity and Delay Models</td>
<td>CR-1998-207659</td>
</tr>
<tr>
<td>Key Metrics and Goals for NASA’s Advanced Air Transportation Technologies Program</td>
<td>CR-1998-207678</td>
</tr>
<tr>
<td>NASA Heavy Lift Rotorcraft Systems Investigation</td>
<td>TP–2005-213467</td>
</tr>
<tr>
<td>Modeling High-Speed Civil Tiltrotor Transports in the Next Generation Airspace</td>
<td>CR-2011-215960</td>
</tr>
<tr>
<td>An Assessment of Civil Tiltrotor Concept of Operations in the Next Generation Air Transportation System</td>
<td>CR-2012-215999</td>
</tr>
</tbody>
</table>