NASA Vision for Rotary Wing Propulsion Research

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Outline

• Overview
• Future Vision for Rotorcraft
• Technical Challenges
• NASA Rotary Wing Project
• Propulsion Research Emphasis
• Concluding Remarks

Loss bucket for EEE tip-section over variable-speed power turbine range

$i-i_{des}$, deg.
Goal: Develop and Validate Tools, Technologies and Concepts to Overcome Key Barriers for Rotary Wing Vehicles

- Acoustic Research
- CFD Methods
- Rotor Systems
- Mechanical Components
- Materials & Structures
- Engine Research
- New instruments and techniques
NASA Rotary Wing Project

Directed to focus on:

– NextGen Rotorcraft Developments
– Mobility / Capacity
– Efficiency
– Energy and Environment
Providing a Vision for Aviation

Challenges for commercial rotorcraft with Entry Into Service in 2030

The Need

- Identify advanced airframe, rotor and propulsion concepts and enabling technologies
- Guidance for NASA investments in fundamental research

NASA Rotary Wing Approach

- Stimulate thinking in industry and academia on revolutionary aircraft solutions
- Determine high-payoff technologies and research opportunities
- Address performance, efficiency, environmental, and operations goals
- Fundamental Research portfolio robust to many possible futures

NASA Rotary Wing Contribution

- Providing the vision and focus for the fundamental research needed today to enable the far term outcomes/products, but with near/mid-term impact and technology transition

Sample Technologies

- Variable speed, high performance, low noise rotor systems
- Efficient engines over wide operating range
- Light weight, efficient drive systems
Providing a Vision for Aviation

Challenges for military rotorcraft with Entry Into Service in 2030

The Need

• Identify advanced airframe, rotor and propulsion concepts and enabling technologies
• Guidance for NASA investments in fundamental research with Army partners

NASA Rotary Wing Approach

• Partner closely with Army for collaborative rotorcraft research
• Determine high-payoff technologies and research opportunities
• Address performance, efficiency, environmental, and operations goals
• Fundamental Research portfolio robust to many possible futures

NASA Rotary Wing Contribution

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Sample Technologies

- Variable speed, high performance, low noise rotor systems
- Efficient engines over wide operating range
- Light weight, efficient drive systems
# Current Common Rotary Wing Configurations and Missions

$6.4B New Civil Purchases in 2012*
1400 New Civil Units in 2012*

<table>
<thead>
<tr>
<th>Configurations (Definition follows DOD convention for rotorcraft)</th>
<th>Light</th>
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</table>
| **Missions**                                                  | •police
•training
•traffic/news
•power line service
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•EMS
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•tourism
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•charter service
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•firefighting |

*From Vertiflite article by Forecast International*
## Envisioned Common Configurations and Missions in 2030 and beyond

### Configurations

(Definition follows DOD convention for rotorcraft)

<table>
<thead>
<tr>
<th>Configurations</th>
<th>Very Light</th>
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autonomous capability

**blue highlight: new mission and/or new configuration**
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<td>Technology</td>
<td>•autonomous and</td>
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<td>•payload</td>
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<td>•noise</td>
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(Definition follows DOD convention for rotorcraft)
NASA RW decision:
Highlight the mission that has the strongest potential to benefit the airspace system and technologies that benefit to the widest range of configurations. Working UltraHeavy configuration is high-risk, high-payoff.

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System Study Results

Recent System Studies:
- NASA Heavy Lift/ Large Civil Tiltrotor (LCTR2)
- Future Concepts in the NextGen
- Technology Benefit Assessment for Compound and Tiltrotor Systems
- Tiltrotor Fleet Operations in the NextGen

Status/Results
- Vertical capability at one or both ends of a 300-600nm mission increases airport capacity.
- Large, advanced technology tiltrotors consistently outpace other configurations in the ability to meet transportation mission
- Advanced technologies give tiltrotors cost and operational parity with configurations already in use
- In latest 3 studies (2010, 2011) Civil tiltrotors show capability to improve airspace system performance significantly; identified technical barriers to overcome
NASA decision: Working these technologies because they have a broad range of applications. Getting most bang for the buck while providing focus on revolutionary technologies.

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### Technologies
- autonomous capability
- weight
- speed
- safety
- payload
- SFC
- green
- range
- noise

NASA decision: Working these technologies because they have a broad range of applications. Getting most bang for the buck while providing focus on revolutionary technologies.
Challenges for Future Rotorcraft

Active Rotor Systems

NextGen Integration

Low Noise: External and Internal

Modeling and Validation

Propulsion System
Technology Benefit Study

Study Objective: assess technologies that have significant benefit for Single Main Rotor Compound (SMRC) and Civil Tiltrotor (CTR) configurations

- Conducted by Boeing under NASA contract
- Results published: NASA Contractor Report 2009-214594
- Metric: Direct Operating Cost per Available Seat Mile (DOC/ASM)

Results: Most beneficial categories (benefit amount depends on the configuration)

- Engine fuel flow
- Structural weight
- Drive system weight
- Parasite drag
- Rotor hover and cruise performance

Investment in these technologies provides benefit to both compound and tiltrotor configurations
FY13 RW Key Elements/Areas of Research

**FY13 SRW Project Summary**

~95 work/years (78 CS / 17 Contractor)
~ $24M per year (includes salary)
Host is LaRC

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**Ames Research Center**
~30 work/years
- Aeromechanics
- CFD
- Flt Dyn & Ctrl
- Exp Capability
- System Analysis

**Glenn Research Center**
~33 work/years
- Drive Systems
- Engines
- Icing
- System Analysis
- CBM

**Langley Research Center**
~32 work/years
- Acoustics
- Aeromechanics
- Exp Capability
- CFD
- Crashworthiness

*based on FY13 President’s budget*
SRW Major Facilities

FY13 SRW Project Summary*

~95 work/years (78 CS / 17 Contractor)
~ $24M per year (includes salary)

Ames Research Center

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

Glenn Research Center

- Compressor Test Facility (CE-18)
- Linear cascade test facility (W22)
- Transmission Test Facilities (ERB)
- Icing Research Tunnel

Langley Research Center

- 14- by 22-Foot Subsonic Tunnel
- Transonic Dynamics Tunnel
- Landing and Impact Research

*based on FY13 President's budget
RW 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)
Key Technical Areas

Technical Challenges
• Demonstrate variable speed power turbine with 50% improvement in efficiency lapse rate over wide operating speed
• Demonstrate two-speed drive system with less than 2% power loss while maintaining current power-to-weight ratios
• Quantify performance, noise and vibration benefits of 3 Active Rotor concepts by test and analysis
• Demonstrate 35% improvement in accuracy of predictions for rotor loads and performance for both hover and forward flight.

Additional Areas of Emphasis
• Demonstrate technologies required for community and passenger acceptance of large rotorcraft operating in the National Airspace (NAS)
Advanced Efficient 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
Variable-speed power turbine (VSPT)

- Conceptual & 3-D blade design/analysis (in-house)
- Assessed in-house paths to VSPT component test
- Down-selected Walters-Leylak transition model for RANS tools
- Transonic linear cascade facility modified; testing of incidence-tolerant blade set complete
- Rotordynamics evaluated
- Rolls-Royce and Williams Int. RTAPS contracts completed
- Collaboration with Army Aviation Applied Technology Directorate (AATD); exploring applicability to FATE-class engines

**Significance:** New innovative concept to enable efficient, wide-range turbine operation.
High Efficiency Centrifugal Compressor (HECC)

- Pre-test grid-generation and URANS CFD (CC3 & HECC) completed; post-test CFD on-going
- High-response p0-probe developed
- Completed detailed mapping of HECC compressor in CE-18. Data collected at corrected speed lines between 55% and 104%, at multiple impeller-to-shroud tip-gap settings.

**Significance:** Knowledge gain will advance the SOA compressor technology to enable new lighter weight/high efficiency compressor needed to power the next generation of variable speed rotors (cost-shared effort with UTRC)
Engine cycle studies

- Current work on TBC’s and CMC’s addresses the need for higher T4.
- Recent studies indicate that fuel burn continues to improve with OPR ~45 and T4~3200.
- Impeller technologies needed to achieve the required OPR (higher T3) are being considered.
Concluding Remarks

- RW is focused on high-risk, high-payoff area with strong ties to National and NASA Aeronautics Goals
- Investment in technologies is broadly applicable to wide range of configurations and missions
- Partnerships (DOD, industry, university) are key to many research areas
- Future vision of civil airspace includes rotorcraft as essential piece of transportation system