Penn State Vertical Lift Research Center of Excellence

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ces5@psu.edu

http://www.engr.psu.edu/rase/

Army/Navy 2007 Annual Program Review
April 3-4, 2008

Management Review

• Center’s program as a whole
  - technical merits
  - relevance
  - technology transfer
  - leveraging resources
  - educational quality
  - cooperation inside and outside

• Contribution to the Vertical Lift Community
  - technology
  - quality students
  - help industry’s competitiveness
For Each Task:
- Technical Merits
- Relevance
- Technology Transfer / Technical Approaches

Emphasis on
- basic research in nature, but relevant
- unique technical contribution
- creativity, innovation

Guidelines for Presentations:

- 20-25 min (max) for presentation
- 5-10 min for discussion

- Explain in terms of physics, physical phenomena
  - technical barriers / challenges
  - unique contribution
  - innovation, new concepts, new understanding

- Don’t spend time on equation derivations, test setup, or code/grid developments
  (use as backup material, if wanted)

- Last year accomplishments
Review Members

- Help presenters to keep their assigned presentation time
- Need good technical discussion after presentation
  - basic research
  - relevance
- No Funding issues

AGENDA – VLRCOE & Navy Program Reviews

Wednesday, April 2

Location: Atherton Hotel

8:30 – 8:40 Opening Remarks (Rutkowski/Kinzer)
8:40 – 9:20 VLRCOE Overview (Smith)

Applied and Computational Aerodynamics /Dynamics
9:20 – 10:05 Army Task 8 Mini trailing Edge Effectors (Gandhi, Maughmer)
10:05 – 10:30 Army Task 6b Rotor Blade Erosion (Camci)
10:30 – 10:55 Navy Task 061 Rotor Flowfield/Ship Airwake Coupling (Long/Horn)
10:55 – 11:05 BREAK
11:05 – 11:30 Navy Task 063 Active Rotors for Enhanced Shipboard DI Ops (Smith, Rahn, Conlon)
11:30 – 11:55 Army Task 2 Overset CFD (Duque)
12:00 – 12:30 LUNCH
12:30 – 1:00 LAB TOUR
1:00 – 1:25 Navy Task 072 Active Rotor Loads Control (Smith, Wang, Rahn)

Ducted Fan Air Vehicles
1:25 – 1:55 Navy Task 074 Wind Tunnel Testing and CFD for FANCRAFT (McLaughlin/Long)
1:55 – 2:20 Navy Task 075 Rotor Dynamics Analysis and Design for FANCRAFT (Smith)
2:20 – 2:45 Army Task 3 Ducted Rotor Tip Casing (Camci)
2:45 – 3:10 Navy Task 065 Flight Simulation of Advanced Ducted Fan Air Vehicles (Horn)
3:10 – 3:20 BREAK

Drive Systems
3:20 – 3:55 Army Task 10 Planetary Gear Dynamics (Parker)
3:55 – 5:15 Day 1 Review Team Caucus
5:15 – 6:00 Day 1 Debriefing
7:15 Informal Dinner
AGENDA – VLRCOE & Navy Program Reviews
Thursday, April 3
Location: Atherton Hotel

Aeroacoustics
8:00 – 8:40 Army Task 1 Interactional Aerodynamics & Acoustics (Brentner, Rajagapolan)
8:40 – 9:05 Army Task 9 Acoustic Scattering (Brentner, Morris)
9:05 – 9:30 Navy Task 076 Aeroacoustics of Advanced Ducted Fan Vehicles (Brentner)

Affordability
9:30 – 9:55 Army Task 11 Avionics Software (Leach)
9:55 – 10:10 BREAK

Variable Speed Rotors: Aeromechanics and Drive Systems
10:10 – 10:35 Navy Task 073 Perf, Vibration, & Noise of Variable RPM Rotorcraft (Gandhi)
10:35 – 11:00 Army Task 7 Variable RPM Rotor Flight Control (Horn)
11:00 – 11:25 Navy Task 062 Drive System for Variable RPM Rotors (Smith et al)
11:30 – 12:15 Lab Tour
12:15 – 12:45 Lunch
12:45 – 1:25 Army Task 4 Rotor Blade Structures (Bakis, Smith, Koudela)
1:25 – 1:50 Army Task 5 Nanotube Composites (Koratkar)
1:50 – 2:25 Army Task 6a Rotor Blade Anti-Icing (Smith, Rose)
2:25 – 2:35 BREAK
2:35 – 3:05 Navy Task 066 Crashworthy Systems for High Mass Payload Items (Bakis, Yukish)
3:05 – 3:30 Navy Task 071 Crashworthy Structures via Cellular SMA Honeycomb (Gandhi)
3:30 – 4:45 Day 2 Review Team Caucus
4:45 – 5:30 Day 2 Debriefing

2007 VLRCOE Management Overview

Army VLRCOE (via AATD)

Navy 6.1 (via ONR)

• Research Thrusts
• Educational Activities
• Technology Transfer & Leveraging
• Statistics
• Strategic Plans
VLRCOE Goals and Technical Approach

General Approach:

1) Develop new design tools, materials, and processes to impact performance and cost

2) Analytical and computational methods that allow prediction of complex behavior and enhance physical understanding

3) Experiments to guide and validate analyses

4) Balance of computation and experiments

5) Educational initiatives

Army VLRCOE Research Thrusts

PSU + Team Technology Strengths

Advanced materials for improved rotor and drivetrain systems

Parallel computations for coupled aeroacoustics & aeromechanics

Innovative and effective educational initiatives

Active sound and vibration control techniques quieter and safer

Health and Usage Monitoring Systems

Guided waves and ultrasonics

Advanced flight controls for improved safety and pilot workload

VLRCOE Thrust Areas

- Aeromechanics
- Material Strength & Fatigue
- Adverse Weather/Environment
- Rotor/Flight Controls
- Vibration and Noise Control
- Prognostics & Diagnostics
- Propulsion
- Affordability
USN Research Thrusts

**PSU + Team Technology Strengths**

- Advanced materials for improved rotor and drivetrain systems
- Parallel computations for coupled aeroacoustics & aeromechanics
- Innovative and effective educational initiatives
- Active sound and vibration control techniques quieter and safer
- Health and Usage Monitoring Systems
  - Guided waves and ultrasonics
  - Advanced flight controls for improved safety and pilot workload

**USN Thrust Areas**

- Survivability
- Safety
- Maritime Performance
- Innovative Concepts
- Propulsion and Drive systems
- Aeromechanics
- Vibration Control
- Diagnostics and CBM

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**Vertical Lift Center Tech Base**

- 25 Faculty
- 40+ Graduate Students
- 100 Undergraduate Students (Freshman Sem, AHS Chapter, Senior Class, Design projects)
- 40 Continuing Education Students (Short course)
Vertical Lift Center Faculty @ PSU

**Director**
- Ed Smith: dynamics, aeromechanics

**Deputy Directors**
- Ken Brentner: aeroacoustics, VLRCOE Admin
- Farhan Gandhi: dynamics and smart structures, VLRCOE Education

**Associate-Directors**
- Joe Horn: flight mechanics and control
- Lyle Long: aeroacoustics, CFD, high perf computing
- Kon-Well Wang (ME): smart structures, structural control

**Administrative Aides**
- Debbie Jacobs (RCOE), Greg Johnson (ARL)

**Affiliated Faculty - Aerodynamics, Aeroacoustics, and Flight Controls**
- Barnes McCormick: aerodynamics, stability & control
- Phil Morris: aeroacoustics
- Mark Maughmer: airfoil design, aerodynamics
- Cengiz Camci: experimental fluid mechanics and heat transfer
- Rob Kunz (ARL): CFD, multi-phase flow, propulsion and gears

VLRCOE Center Faculty @ PSU

**Affiliated Faculty - Structures and Dynamics**
- George Lesieutre: structural dynamics, materials
- Chuck Bakis (ESM): composite structures
- Gary Koopmann (ME): structural acoustics, smart structures
- Bill Mark (ARL): Gear optimization and noise
- Mary Frecker (ME): Compliant mechanisms, optimization
- Tom Donnellan (ARL): Manufacturing, Advanced Composites
- Joe Rose (ESM): Ultrasound, NDE, guided waves, icing
- Kevin Koudela (ARL): Composite structures, nanomaterials, FEM
- Bob Bill (AERSP): Propulsion and powertrains
- Eric Mockensturm (ME): Smart structures
- Mike Yukish (ARL): Crashworthiness, optimal design
- Suren Rao (IE, ARL): Drivetrain technologies, manufacturing

**Affiliated Faculty and Research Scientists - Condition Based Maintenance**
- Stephen Conlon (ARL): HUMS, sensors, data fusion
- Karl Reichard (ARL): HUMS, signal, processing
- Jeff Banks (ARL): HUMS System integration
- Asok Ray (ME): Damage Detection, Failure mechanics
**Off-campus VLRCOE Faculty Partners**

Koratkar (RPI)  
Nanomaterials  

Parker (OSU)  
Gear & drive system dynamics  

Dr. Earl Duque  
(Intelligent Light)  
Rotorcraft CFD  

Leach (Howard)  
Software Engineering  

Rajagopalan (ISU)  
CFD

**New VLRCOE Faculty & Staff Contributors/Collaborators**

“We are committed to seeking collaborations with the “best and brightest talent”

Here at Penn State:

Chris Rahn (PSU ME)  
Control, structural dynamics  

Ralph Noack (PSU ARL)  
CFD, Overset grids, multiphase flows  

And beyond….  

Wade Huebsch (WVU)  
CFD, Ice Accretion, flow control  

Hans DeSmidt (U Tenn)  
Active control, driveline dynamics, HUMS  

Kon-Well Wang (ME)  
smart structures, structural control
**NASA RFA Programs**

- 2 selected proposals from NASA Glenn Research Center
  - Integrated Propulsion System Modeling
    - (Wang, Smith, Bill, DeSmidt @ Univ of Tennessee)
  - Gearbox Windage Loss CFD
    - (Kunz, Morris, Long)

- 1 selected proposals from NASA Langley Research Center (Ga Tech prime)
  - Innovative Overset Grid Connectivity Software for Unstructured Rotorcraft Simulations (Noack)

- Approx $600K per year total x 3 years (7 graduate students)
  - January 2007 and 2008 starts

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**Other DoD Programs**

- Army Research Office
  - Structural Damping and Health Monitoring Enhancement via Multifunctional Carbon Nanotube Based Composites Tailoring (Bakis, Wang)

- Office of Naval Research
  - X-Hawk Engineering Analysis and Feasibility Study (Smith, McLaughlin)

- Army Ames
  - Airfoil Testing and Design Support (Maughmer, Airfoils Inc. with Somers)
  - Airframe Vibration Control (Smith, Rahn , INVERCON. with Szefi)

- Army AATD
  - Structural Health Monitoring (Conlon, Smith)
  - Nonthermal Anti-Icing (Rose, Smith, FBS with Royer)
  - Piezo Flap Actuators (Smith, Mockensturm , INVERCON. with Szefi)

- DARPA
  - Gear Health Monitoring (Mark, with Northrup/Grumman)
  - Nastic Structures (Bakis,Wang, Rahn, et al)
Army-Navy-NASA-CRI Leveraging

- Composite rotor development to reduce heavy lifter rotor weight

Army: materials and structural concept advances  
Navy: Active loads control  
CRI: Rotor system damage detection

<table>
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<tr>
<th>cR</th>
<th>0.25</th>
<th>0.50</th>
<th>0.75</th>
<th>1.0</th>
<th>Overall blade weight reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight reduction</td>
<td>20%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>54%</td>
</tr>
</tbody>
</table>

- Variable Speed Rotorcraft

Army: Flight control laws  
Navy: Mechanical Transmission System  
Navy: Active Loads and Vibration Control  
Navy: Morphing Variable Speed Rotors  
NASA: Propulsion and Drive Elements
Army-Navy-NASA-CRI Leveraging

- **Safety and Survivability**

  Army: anti icing systems
  Army: erosion control
  Army: blade impact protection
  Army: aeroacoustics
  Navy: crashworthiness for internal payloads
  Navy: Innovative Configurations
  CRI: CBM rotor damage detection

- **Facilities**

  Army supported rotor test stands can be used for USN projects
  Army supported drive system test stands can be used for Navy projects
  Army & Navy supported flight simulation facilities can be shared
  Army & Navy computing facilities can be leveraged and shared
  Synergy in curriculum and educational outreach
CRI and Industry Programs
(new in Blue)

- Damper Modeling (Bell, LORD Corp)
- Drive Systems (PURDY Corp)
- Rotor Blade Anti-icing (Bell, FBS Inc. AATD SBIR)
- High Authority TEF actuation (INVERCON LLC AATD SBIR)
- Flexible Composite Driveshafts I (Bell, Boeing, Goodrich, Kaman CRI)
- Rotor System Damage Detection x 3 (CRI)
- Shipboard Flight Simulation and Controls (Sikorsky, CRI)
- Tiltrotor Stability Augmentation (Bell, CRI)
- Structural Health Monitoring (AATD)
- Blade Erosion (UTRC, Sikorsky, CRI)
- Structural Durability Tech (Rhombus, NAVAIR SBIR)
- Time Domain Airframe Vib Control (INVERCON, AFDD SBIR)

Educational Activities

- 1st Year: Hand’s on Helicopters 101 (Smith/Bill)
- Rotorcraft Aerodynamics (Gandhi/Smith)
- Rotorcraft Dynamics (Smith/Gandhi)
- Rotorcraft Stability and Control (Horn)
- Rotorcraft Propulsion (Bill et al)
- VSTOL Aerodynamics (McCormick et al)
- Rotorcraft Lab and Design (Smith, Bill et al)
- Aeroacoustics (Morris, Brentner)
- Parallel Computing (Long)
- Structural Dynamics (Lesieutre/Wang)
- Smart Structures (Gandhi)
- Summer Short Courses (McCormick et al)
- AHS Design Competition
- Lab tours and educational programs for preK-HS kids
- TV and www Courses (Expanded VLRCOE classes)
**Student Population**

- **Graduate students at PSU**
  - 55 total Full-time Graduate Students
  - 13 on VLROCE
  - 13 + 1.5 postdoc on ONR
  - 2 Army Officers (pilots)

- **Graduate students at Partner Universities**
  - OSU (3), RPI (2), ISU (1), Howard

- **Undergraduate students**
  - 13 in 2 separate AHS Student Design Teams
  - 15 in Undergrad Senior Elective- Helicopter Aero I
  - 15 in Industry-sponsored Design-Build-test
  - 40 in First Year Seminar (Hands-On Helicopters)

**Student Recognition**

- Bell Helicopter Graduate Fellow: Stan Sollenberger
- NASA Graduate Student Research Fellow: Mike Theil
- DoD Fellowship Winner: Gabe Murray
- Lord Corp Graduate Fellow: Conor Marr (Fluidlastic Dampers)
- ONR Fellow (Terry Johnson)
- 2008 AHS Lichten Internship Winner: Conor Marr
  “Time Domain Modeling of Fluidlastic Lag Dampers”

- 2 Vertical Flight Foundation Fellows in 2007
  (Len Lopes, Pam Montanye)
- 4 Vertical Flight Foundation Fellows in 2008
  (James Erwin, Ed Brouwers, Chandrashekar Tiwari, Conor Marr)
- 1st Place in Undergraduate AHS Design Competition, 2007 (with Technion)
AHS Student Design Competition
2007: Sikorsky Sponsored

**RFP Requirements:**
- Two seat automatic ARV for SOF missions
- Storage and operation from SSCN
- Impervious to water and all weather operable
- HOGE capability at 6[kft]/95[°F]
- 800[lbs] Payload

**Mission:**
- Launch from SSCN at 50[ft] periscope depth, within 30[min] of task receipt
- Take off within 10[min] after being positioned on the water surface
- Fly 140[nm], unload/pickup 2 SOF crew and return
- Land on water, recede beneath water surface within 10[min]

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1st Place - Undergraduate

<table>
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<tr>
<th>Dimension</th>
<th>Value</th>
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<tbody>
<tr>
<td>Gross Weight [kg]</td>
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</tr>
<tr>
<td>Empty Weight [kg]</td>
<td>600</td>
</tr>
<tr>
<td>Payload [kg]</td>
<td>402</td>
</tr>
<tr>
<td>Number of seats</td>
<td>2</td>
</tr>
<tr>
<td>Rotor Diameter [m]</td>
<td>5.2</td>
</tr>
<tr>
<td>Fuel weight [kg]</td>
<td>200</td>
</tr>
<tr>
<td>MRP [HP]</td>
<td>660</td>
</tr>
<tr>
<td>Total Diameter [m]</td>
<td>2.08</td>
</tr>
<tr>
<td>Total height [m]</td>
<td>3.46</td>
</tr>
<tr>
<td>Number of Blades</td>
<td>4</td>
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</table>
While rising, flotation devices are deployed. Once in float, the engine is warmed up and the Anti-icing system is turned on.

Flotation devices fold in for a smooth flight:

Take off occurs:

Blades are deployed:
Control box

Mockup experiment, Jan. 2007

Waterspout’s Bottom door

VLRCOE Highlights

- Icing Wind Tunnel Testing with Goodrich/Bell
- Flap Actuator Testing
- Airfoil Design and Testing
- Comprehensive Ducted Fan Vehicle program
- Variable Speed & Morphing Rotor
  Popular Mechanics Breakthrough Award (Gandhi)
- Structural Health Monitoring
- Propulsion and Drive Systems
- 2008 DURIP Instrumentation Grants
- AHS Student Design Competition Winner (2007)
- AHS J. Editorship (K. Brentner)
Ducted Fan Projects at Penn State

Profs. Horn, McLaughlin, Long, Smith, Brentner and Camci
and numerous graduate students

Department of Aerospace Engineering
Penn State University

April, 2008

Ducted Fan Air Vehicles

Projects Currently Being Pursued

- Navy Task 065  Flight Simulation of Advanced Ducted Fan Air Vehicles (Horn)
- Navy Task 074  Wind Tunnel Testing and CFD for FANCRAFT (McLaughlin / Long)
- Army Task 3    Ducted Rotor Tip Casing (Camci)
- Navy Task 075  Rotor Dynamics Analysis and Design for FANCRAFT (Smith)
- Navy Task 076  Aeroacoustics of Advanced Ducted Fan Vehicles (Brentner)
**Background**

- Ducted rotors have been applied as anti-torque device (fenestrions) as well as main lifting devices
- **Ducted rotor suits the mission of urban operation well (UAV, compact VTOL vehicles)**

![Solo Trek XFX Ducted Rotor Millennium Jet Inc.](image1)

![The Sikorsky MARINER/Cypher II](image2)

![Piasecki “Flying Jeep”](image3)

![Urban Aronautics “X-Hawk”](image4)

![Ducted fan tail rotor of the RAH-66 Comanche](image5)

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**Background**

**Advantages of Ducted Fan Systems**

- **Smaller Footprint:** Vehicle can be made more compact due to added lift of the duct - suited for operating in confined spaces.
- **Safety:** Rotor shroud protects the rotor from external hazards
- **Control:** Ducted fans can use vanes for flight control, adding redundancy or simplifying the mechanical control system.
- **Reduced Noise:** The rotor shroud provides some acoustic shielding.
**Background**

- In forward flight, significant amount of drag and duct pitching moment have adverse effect on vehicle performance and flight control. *(ATI, 1991; Fleming, J., et al, 2004)*

- Ducted rotors may adopt the hingeless hub configuration to avoid complex cyclic control to reduce weight, drag, and maintenance cost. However, it may also experience considerable lift asymmetry and large blade bending moments.

**Classes of Ducted Lift Fans**

- We can divide the ducted lift fans into two classes:
  1) Those that also derive thrust from the lift fans
  2) Those whose thrust is predominantly provided from an alternate source.

Urban Aeronautics “X-Hawk”
Classes of Ducted Lift Fans

- The major aerodynamic problems with these two classes of ducted fans are distinctly different.

- Our research teams are addressing basic research topics relevant to both of these types of ducted fans.

Next Generation Ducted Fan Air Vehicles

Breakthrough technology for compact vehicles

Breakthrough technology for urban warfighters

Numerous configuration applications (manned and UAV)

Strong industry and DoD interest

International technology partnership
Structural Health Monitoring

• 6 Active Grants (US Army, NAVAIR, DARPA, industry)

• New Ben Franklin Center with Industry (est. 2007)
  Director: Prof Cliff Lissenden (ESM)
  Assoc. Dir.: Prof Ed Smith (AERSP)
  Matching Funds from PA

  - Spur the research and development of new SHM technologies
  - Transfer SHM technologies to member companies
  - Make PA a hotspot for structural health monitoring
  - Train students to provide an outstanding workforce pool

Variable Speed Rotors

• NASA NRA program
• Army VLRCOE Project
• ONR Projects

• Challenges in:
  – propulsion and drives
  – Aeromechanics
  – Adaptive Rotor Design
  – Vibration Management
  – Flight Control Architecture and Design
Popular Mechanics
2007 Breakthrough Award

Prof. Farhan Gandhi
Length Morphing Helicopter Rotor


Airfoil Design and Testing

1) Development and Testing of Miniature Trailing-Edge Effectors for Active Rotor Control

2) Heavy-Lift Helicopter Blade Airfoil Design

3) Active Flow Control via Dynamic Roughness with WVU and ISU

4) Wind Tunnel Testing of Tiltrotor Blade Airfoils with Airfoils Inc (Somers)

5) Low Reynolds Number, High-Lift Airfoil Design for VTOL UAVs
Manufacturing and Materials

Bending Allowables for AMS 6308- sponsored by the Aerospace Bloc of the Gear Research Institute (Avio, Boeing, Curtiss Wright, Honeywell, Latrobe Steel, Pratt & Whitney, Rolls Royce, REM Chemicals, Sikorsky, Timken)

Comparative Durability of Carburizing Stainless Steels - Aerospace Bloc, GRI

Analysis of Bending Fatigue in AMS 6308-Aerospace Bloc, GRI

Near Net Forged Gears-Boeing/Army

Blade repair with FRC East Cherry Point. (Ted Reutzel)

Gear box coating (Tim Eden)

CFD

CFD Simulations of Gearbox Windage Losses, NASA (Kunz et al)

CFD Methods for Rotorcraft Flowfields, NASA via Ga Tech (Noack et al)

Health and Usage Monitoring and CBM

Gear Health Monitoring - DARPA via Northrup Grumman (Mark)

Structural Intensity for Structural Health Monitoring - US Army AATD (Conlon)
New Facility Plans

$200K DURIP Award in 2007 (ONR)
- Rotorcraft Flight Simulators (XV-15, FANCRAFT™)
- Computational Facilities (High Perf Clusters)

2008 DURIP Awards:
ONR ($160K)
- Crashworthiness test stand upgrade
- Composite structures fabrication (filament winder)
ARO ($200K)
- Rotor Test Stand Modifications (balance, actuators, etc)
- Icing Test Facility Improvements (Nozzles, LWC, etc)

Professional Development

Short Courses

1 week Rotary Wing Tech Short Course at PSU - Aug 2007
(McCormick et al)

40th annual offering!

#41 in August 2008

http://app.outreach.psu.edu/RotaryWing/
Current Industry Sponsored Senior Design Projects

1) Vibration Simulation Seat (SIKORSKY)

2) Hover Stand for RC Helicopters (BOEING)

Financial support for teaching assistants, equipment, and supplies provided by BOEING and SIKORSKY

Technology Transfer & Leveraging

2007-08 Travel Highlights

- Visits to Ames (Maughmer, Brentner)
- Visits to LaRC (Brentner, Gandhi)
- Participation in SAE Icing Conf, Spain (Smith)
- Visit to Boeing Mesa (Gandhi, Smith, Hennes)
- Visits to Agusta (Gandhi)
- Visits to ONR (Smith, Bakis, Gandhi, Horn et al)
  - Visit to NAVAIR (Bakis, Smith et al)
  - Visits to Bell (Smith, McLaughlin, Marr)
- Participation in CRI TAC, etc (Smith)
- Attendance at Airloads Workshops (Brentner)

- Invited Seminar at UM and Ga Tech (Brentner)
- Visit Nanjing University of Aero & Astro (Horn)
Technology Transfer & Leveraging
2007-08 Travel Highlights

Participation in DOE Wind Turbine Workshops (Brentner)
Testing at BF Goodrich Icing Tunnel (Smith)
Visits to Lord Corp in Erie (Marr)

Visits to Glenn Research Center
(Wang, Smith, Parker, Kunz, Bill)

Visits to US Army Aberdeen (Bakis)
Visit to Boeing in Philadelphia (Bakis)

Boeing team visit to PSU
Bell seminar & visit to PSU
Lord Corp visit and seminar at PSU

Penn State VLRCOE - NEW Facilities

- Rotor Test Stand with Icing Chamber
- Rotorcraft Flight Simulator (DURIP, Bell)
- Ultrasonic Guided Wave Lab
- Parallel Computing Facilities for Rotorcraft Analysis (DURIP)
- Payload Restraint Test Drop Tower
- Morphing Diameter Rotor Test Rig
- Airframe Vibration Control Testbed (time domain)
Awarded 2007 and 2008 DURIPs

Instrumentation Augmentation Grant (DURIP)

- Flight Simulation facilities
- CFD and CAA computing facilities
- Crashworthy mount testing rig (20 m/s)  FUNDED $300K in 2007
- New Computerized Filament Winder
- Rotor Icing test facility (nozzles, LWC, etc)
- Rotor test stand (actuators, balance cal, etc)

Faculty Recognition & Service

- Dr. Chuck Bakis - Appointed PSU Distinguished Professor
- Dr. Rob Parker - Appointed ASME Fellow
- Dr. Ed Smith – Appointed AHS Fellow
- Dr. Farhan Gandhi – Popular Mechanics Breakthrough Award
- Dr. Farhan Gandhi – AHS Forum Assoc. Tech Chairman
- Dr. Farhan Gandhi – AHS Design and Dynamics Tech Comms.
- Dr. Farhan Gandhi – AIAA Adaptive Structures Tech Comms.
- Dr. Mark Maughmer - – AIAA Adaptive Education Session Chair
- Dr. Ken Brentner – AHS HQ Tech Comm
- Dr. Ken Brentner – Promoted to Professor of
- Dr. Ken Brentner – Editor-in-Chief, AHS Journal
Statistics - 2006-1010 VLRCOE Program

<table>
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<tr>
<th>Year</th>
<th>Prog.</th>
<th>Journal Papers</th>
<th>Conf. Papers</th>
<th>MS degs</th>
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<td>Army:</td>
<td>3</td>
<td>16</td>
<td>3</td>
<td>1</td>
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<td>2008</td>
<td>Navy:</td>
<td>9</td>
<td>3</td>
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Note: Total numbers higher for entire Penn State Vertical Lift Research Program activities (other funds from MURI, ARO, industry, etc.). These totals are available from Prof. Smith.

Total Rotorcraft Research Budget
$3.8M in total 2006 funding

VLRCOE (PSU)
VLRCOE (Sub)
ONR
Sikorsky
Boeing
Bell (XV-15)
Bell
Purdy
Lord
AATD SBIR
Penn State
CRI
NASA
DARPA
Sandia
Total Rotorcraft Research Budget
$4.0M in total 2007 funding)

- X-Hawk
- NASA
- CRI
- PSU
- VLRCOE
- ONR

Total Rotorcraft Research Budget
$5.07 M in total 2008 funding)

- NAVAIR (SBIR)
- AATD (SHM)
- CRI
- DURIPs
- SAC
- Boeing
- DoD/ONR/NASA (grad fellows)
- Lord
- Purdy
- Bell
- Penn State (cost share)
- ARO (core)
- ONR ($1M)
- VLRCOE (Sub)
- VLRCOE (PSU)
- NOAA
- AATD SBIR
- Penn State
- CRI
- NASA
- X-Hawk (ONR)
- AFDD

April 2-3 Review
VLRCOE Strategic Goals: 2007

1) Develop additional key VLRCOE facilities (B)
2) Move out on new ONR, NASA, CRI programs (A)
3) Expand relationship with USAF (C)
4) Expand relationship with industrial partners (A-)
5) Develop distance education programs (C)
6) Unravel mystery of Stonehenge (B)

6) Expand collaborations coordination with VLRCOE at Georgia Tech (B)
7) Develop Vertical Flight Museum (B)
8) Identify solution for US energy independence (B -)
9) VLRCOE Administration (A-)
10) DON’T FORGET TO HAVE SOME FUN! (A-)
2008 Strategic Plans

1) Develop additional key VLROCE facilities
2) Begin to transition VLROCE 6.1 tasks into CRI, SBIR etc
3) Pursue new MURI program with ONR
4) Expand relationship with USAF
5) Develop distance education programs
6) Rekindle Penn State Vertical Lift Museum effort
7) Develop course on Ice Protection Systems
8) Develop research programs in Active Flow Control and CFD Methodology for Ice Accretion

9) VLROCE Administration
   - Update and overhaul WWW pages
   - Prepare compilation of papers

10) as always, DON”T FORGET TO HAVE SOME FUN!

Enjoy the review!!!