Adaptive Rotor Development

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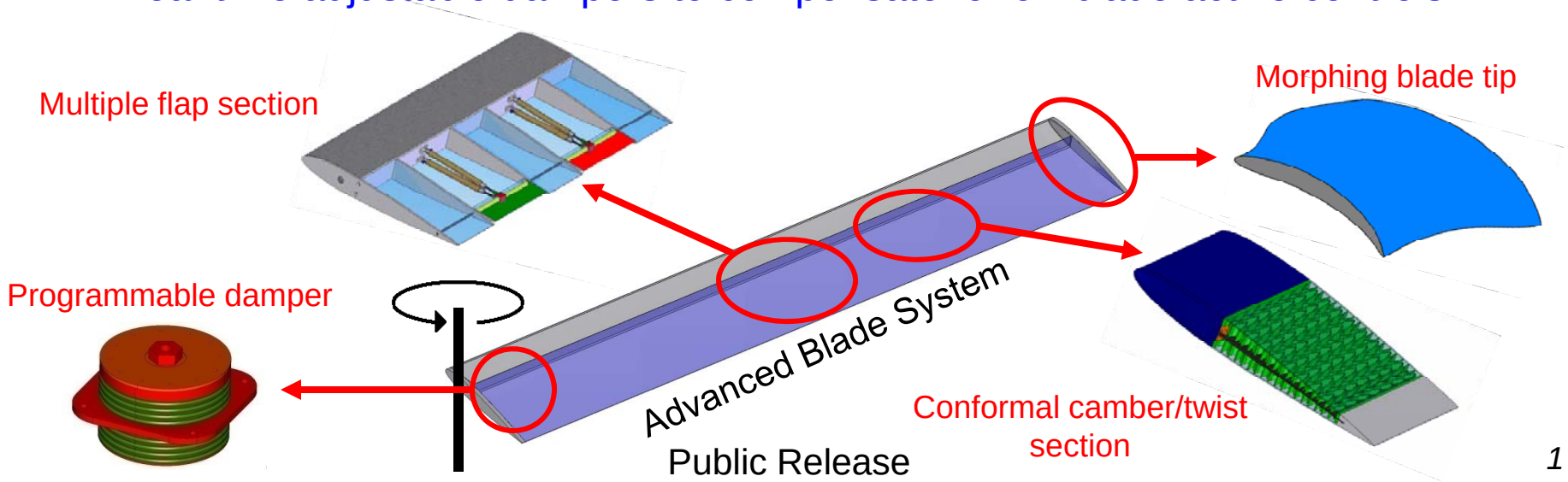
DARPA Mission Adaptive Rotor BAA Industry Day

Public Briefing

3 March 2009

Mission Adaptive Rotor System

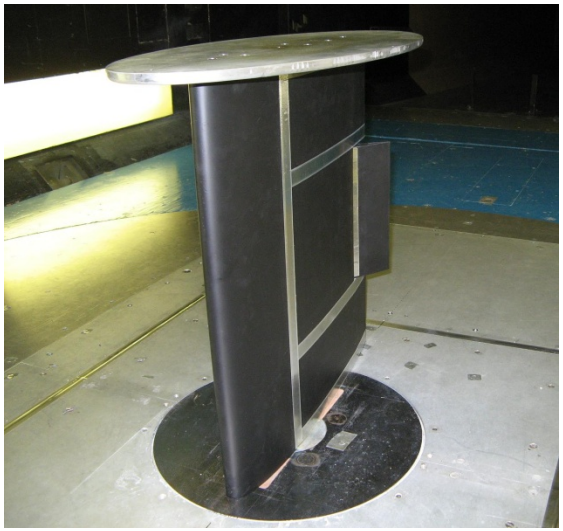
- An opportunity exists for a new paradigm in advanced rotorcraft systems
- Feasibility of enabling technologies was demonstrated
  - High control authority flap actuation (±3 to ±10 deg up to 70 Hz)
  - Substantial damping augmentation (50% to 100%)
  - Broad-scale morphing capability (100% area change)
- Combining enabling technologies will lead to revolutionary advancement in rotorcraft performance
  - Swashplateless rotor
  - Vibration and noise control capabilities
  - Real-time adjustable dampers to compensate for on-blade active controls

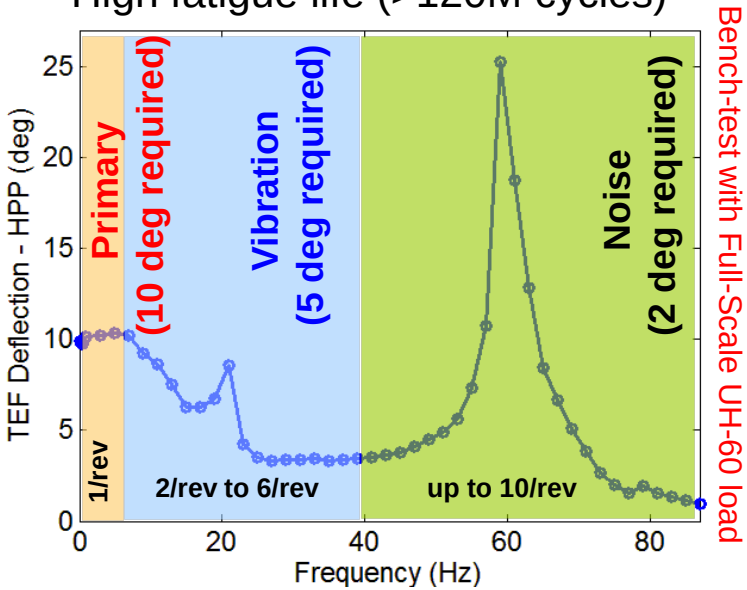


Trailing-Edge Flap Actuation

Pneumatic Artificial Muscles

- Improve flight control → eliminate swashplate
- Reduce vibration → increase blade life, ride quality
- Appropriate for full-scale rotors (F~400 lb; x~1-3 in, 30%)
- Low weight penalty (<0.5 lb)
- High specific work (~500 in-lb/lb)
- Low operation pressure (<100 psi)
- Bandwidth in proper range (1–50 Hz)
- High power density actuation
- Minimum moving parts
- High fatigue life (>120M cycles)





TSi PAMs show promise for full-scale rotorcraft applications

Full-scale UH-60 simulated aero load (Mach 0.56)
- Primary flight control: ±10° up to 10 Hz
- Vibration control: ±3.5° up to 35 Hz
- Noise control: ±1° – ±3.5° up to 80 Hz

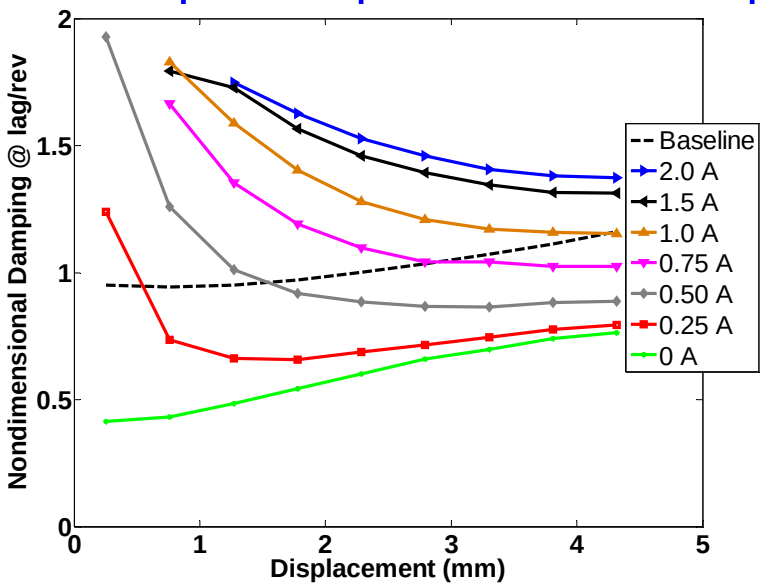
Full-scale Bell 407 simulated aero & 80% CF loads
- ±8° up to 40 Hz at 660 *g*'s

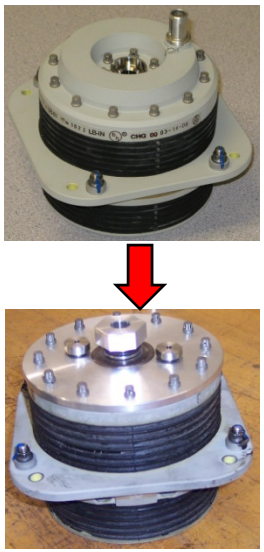
Full-scale Bell 407 simulated aero load (Mach 0.56)
- Primary flight control: ±18° up to 10 Hz
- Vibration control: ±8° up to 35 Hz

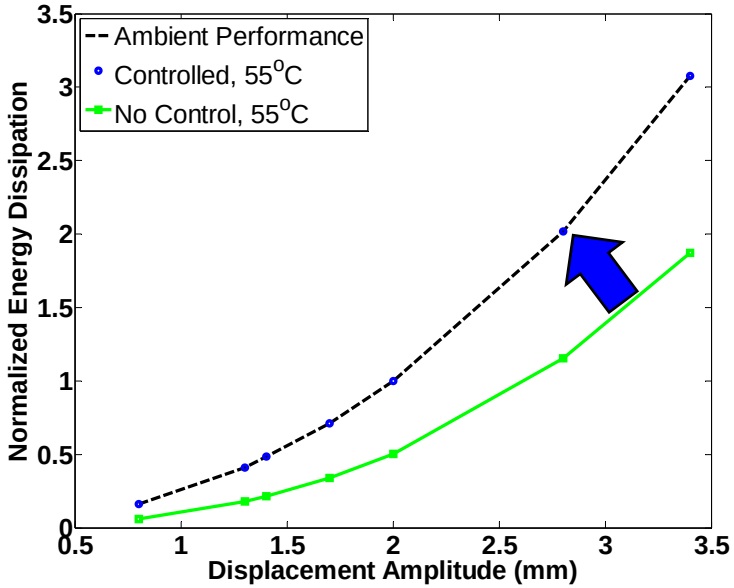
Programmable Lag Damper

Magneto-Rheological Fluids

- Design, retro-fit, & test MR valves in Bell 430 lag damper
  - Achieved 50% to 100% controllable damping authority (lag/rev, 1/rev, & dual frequency)
- Temperature and amplitude compensation
  - Tracked reference damping profile
  - Restored temperature-dependent damping loss
  - Open-loop and closed-loop control systems

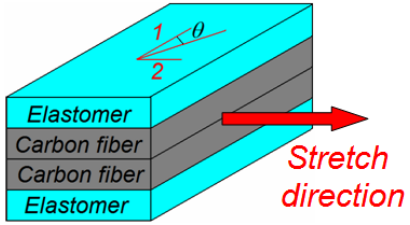


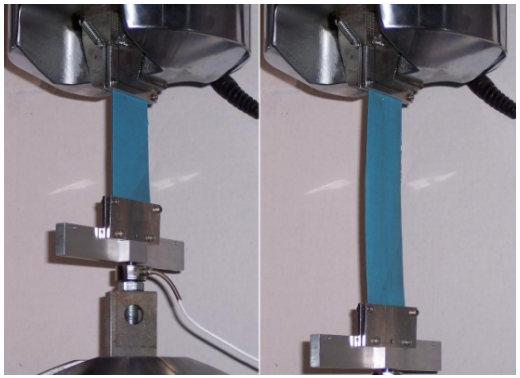


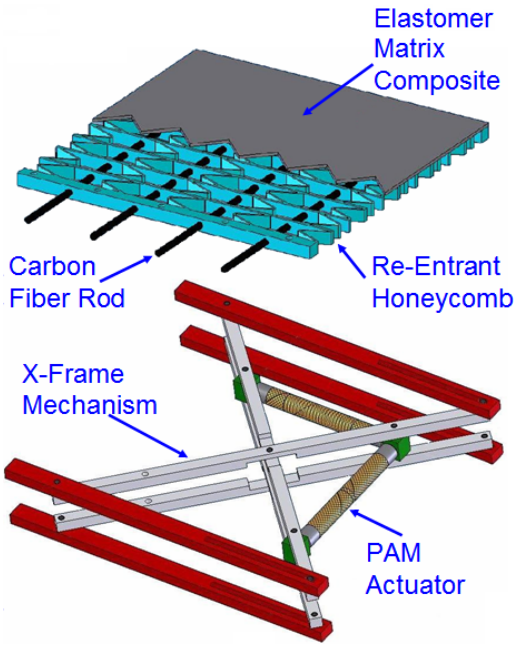


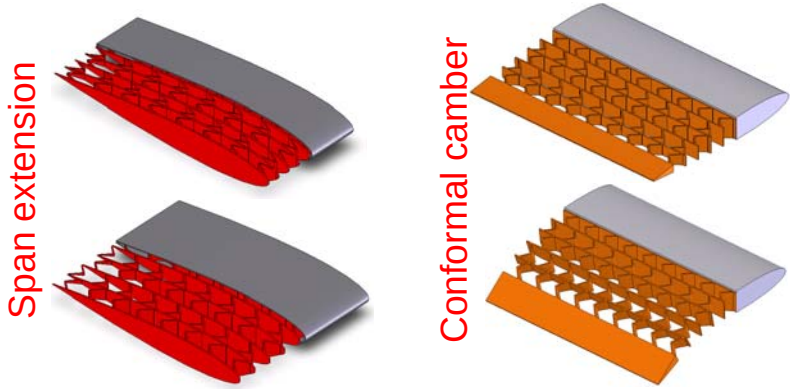
Morphing Structure Development

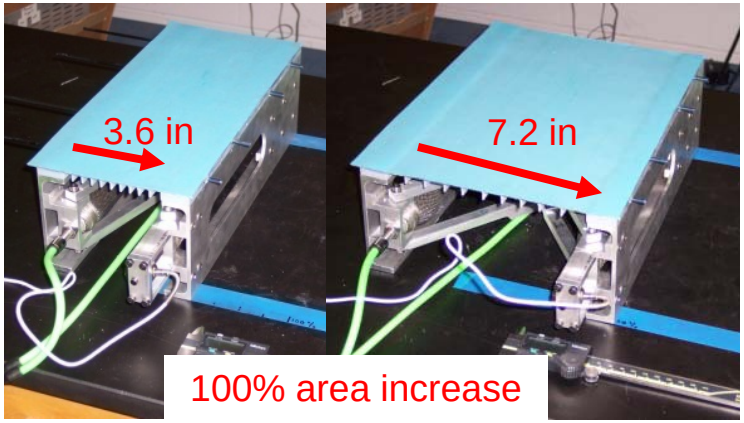
- Morphing system has two key components
  - Reinforced skin
  - Actuation mechanism
- Reinforced skin (passive)
  - Elastomer matrix composite
  - Zero-Poisson core
- Actuation mechanism
  - PAM actuators
  - Tailored mechanical advantage
- Applicable to multiple configurations









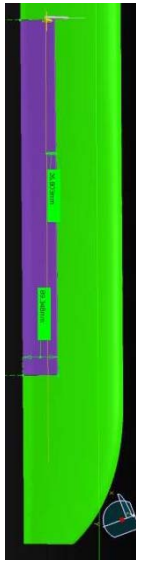


Comprehensive Design:

Hybrid Unsteady Simulation for Helicopters (HUSH)

- UMARC can be run with its own aerodynamics
  - C-81 look-up tables can incorporate 2-D static CFD predictions
  - Useful for preliminary design; validate designs with CFD

- Suite of CFD tools for CFD/CSD coupling from HQP
  - SUmb, SUmb/CDP, UMTURNS, OVERTURNS
  - Loosely coupled to UMARC
  - Acoustic module propagates surface or off-surface data
  - Python used to couple various disciplines - can replace CFD or CSD
  - Validated for UH-60, HART II, MDART/SMART in HQP program
  - Predict performance, vibrations, structural loads, acoustics



- Morphing capabilities added to OVERTURNS
  - Integral TEF with overhang, Leading-edge slat
  - Dynamic droop (camber), Dynamically deforming leading edge
- Tight-coupling for maneuvers (NASA NRA)