University of Maryland (UMD): Alfred Gessow Rotorcraft Center
James Baeder
(baeder@umd.edu)
Mission Adaptive Rotor Industry Day

Maryland Rotorcraft CFD/CSD Capabilities

Mission Adaptive Rotor (MAR) program objectives:

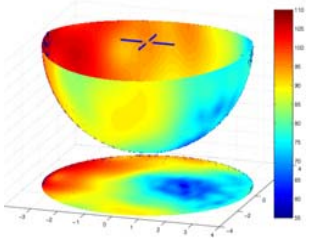
- 30% increase in payload (max C_T and/or C_T/C_P)
  or
  40% increase in specific range (max C_T/C_P)
- 50% reduction in acoustic detection range (low freq., thickness)
- 90% reduction in vibration (active control)

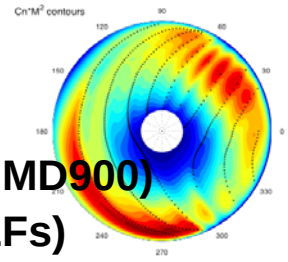
Require emerging CFD/CSD analysis (with *active* capabilities) to both be credible *and* for risk reduction

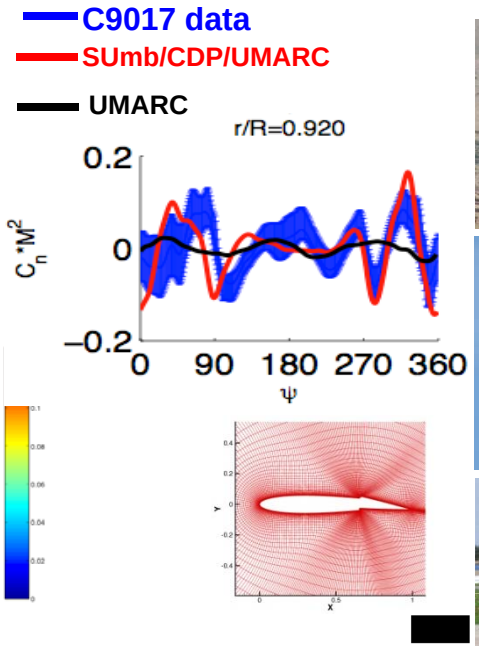
March 3, 2009

Build Upon HQP tools *(HUSH)*

- ***Suite of CFD tools* for CFD/CSD coupling from HQP (HUSH)**
  - **CFD Tools: SUmb, Sumb/CDP, UMTURNS, OVERTURNS**
  - ***Loosely coupled to CSD (UMARC)***
  - **Acoustic module propagates surface *or off-surface* data**
  - **Python used to couple various disciplines: *can replace CFD / CSD***
- **5 rotor configurations**
  - **14 flight conditions**
  - **Extensive validation with test data**
- **Articulated rotors**
  - **UH-60A (including high μ and stall)**
  - **DNW model test rotor**
- **Hingeless rotors**
  - **HART II model rotor**
- **Bearingless rotors**
  - **MDART (pre-production MD900)**
  - **SMART (MDART with TEFs)**



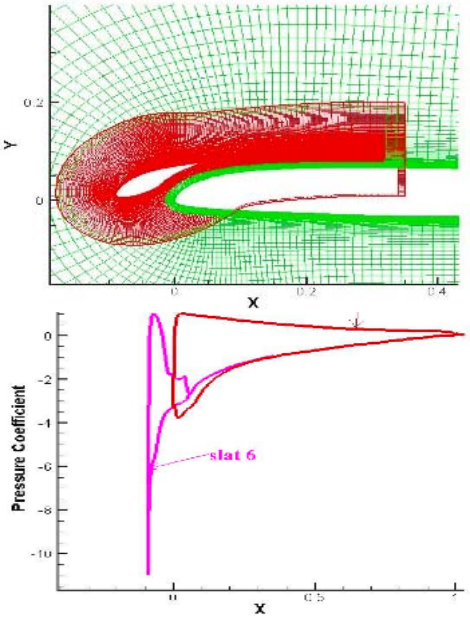




Predict performance, vibrations, structural loads, acoustics

Comprehensive Design for MAR

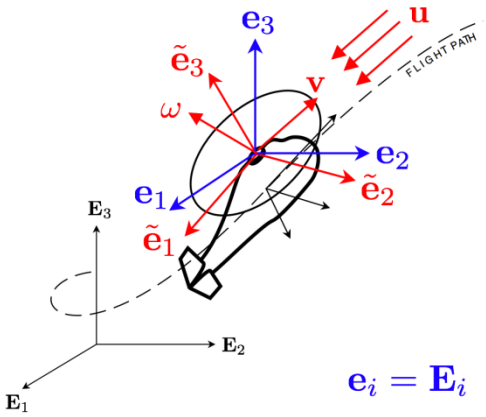
- **Tools we have: Hybrid Unsteady Simulation for Helicopters**
  - **Comprehensive Analysis (UMARC) can be run with it's own aerodynamics**
    - **Use for preliminary design ---> validate designs with CFD (high μ, C_T)**
  - ***Suite of CFD tools* for CFD/CSD coupling from HQP**



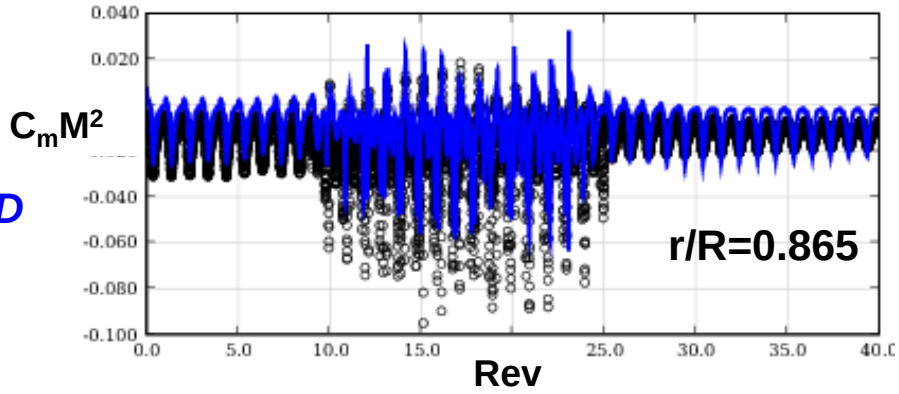
- **Additional CFD/CSD Capabilities:**
  - **Tight-coupling for maneuvers (NASA NRA)**
    - **C11029 UTTAS Pull-up (stall, pitch link loads)**
  - **2-D CFD Generated C-81 look-up tables for UMARC**
    - **TEF, Slatted-airfoils, Morphing airfoils**
  - **Swashplateless Rotor**
    - **Use TEF or Flap/Tab servo**
  - **Detailed wake capturing improvements**
    - **Implicit Hole-Cutting, Fringe Points, (Time-Accurate Low-Mach Preconditioner)**
    - **Especially for Multi-rotors: Co-axial, Tandem, Tilt-rotor**
  - **Morphing capabilities added to OVERTURNS**
    - **Integral TEF with overhang, Leading-edge slat**
    - **Dynamic droop (camber), Dynamically deforming leading edge, ZMSJ**

NASA NRA - Maneuver

- **Collaborative effort between Maryland / Stanford**
  - Three year effort (in second year)
- **Extending CFD/CSD Coupling**
  - Use domain decomposition
  - Sub-structures in CSD to handle large deformations
  - Time marching CFD and CSD
    - Exchange information each subiteration (or timestep)
    - Equivalent to strong coupling



Increase in pitching moments during maneuver predicted by CFD - affects pitch-link loads



Examining C11029 pull-up maneuver for UH-60A flight test

- **Unstructured Overset Connectivity**
  - Adding in hole cutting capability at each time step
  - Examining scalability and efficiency

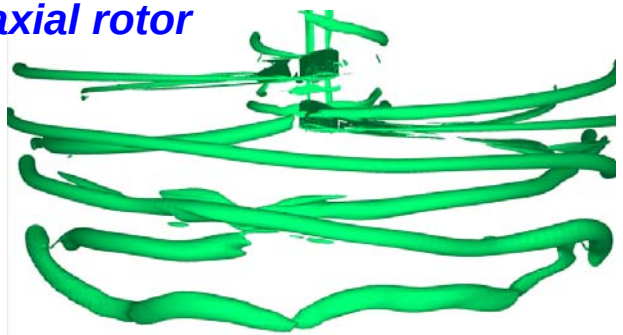
Improved Wake Capturing

- **Implicit Hole Cutting:**
  - Natural determination of fringe point location
    - Cell size or cell diagonal

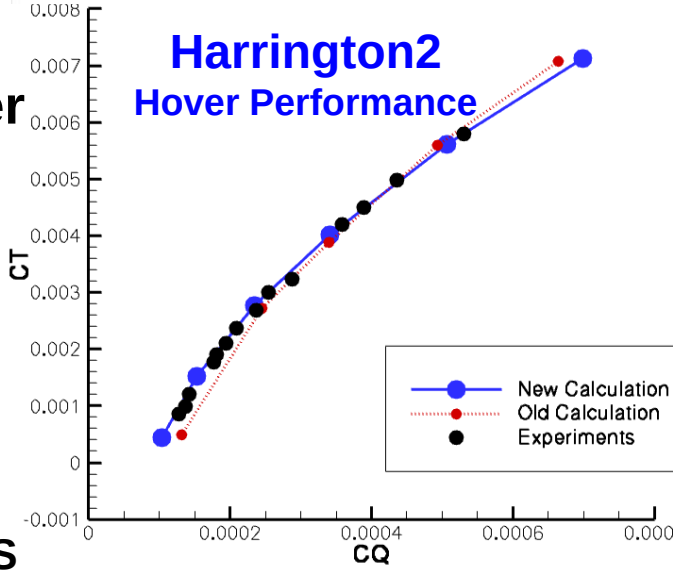
Harrington2 coaxial rotor

Old

New



- **Improved Iblanking**
  - Iblanking used in both RHS & LHS of solver
    - RHS prevents wrong values used for fluxes
    - LHS prevents contamination in implicit inversion
  - Fringe Points
    - Should be used for flux calculation
    - Should not be used in implicit inversion
    - *Need to use different iblank for fringe points*
    - Define iblank = -1 for fringe points
    - Use abs(iblank) for RHS and max(iblank,0) for LHS



Morphing Capabilities

Slice of 3-D deforming rotor with dynamic leading-edge slat

- **Morphing capabilities available for OVERTURNS:**
  - Dynamic droop (camber)
  - Dynamically deforming leading edge
  - Zero-mass synthetic jets
  - Integral TEF with overhang
    - Gap-averaging
  - Leading-edge slat
    - Dynamic Implicit Hole Cutting
- **Note for MAR:**
  - **Flight Condition** (slowly varying)
    - Variable Diameter
    - Variable RPM (High μ)
      - CFD captures reverse flow
  - **Swashplateless**
    - E.g., Softer in torsion w/ TEF

Emerging CFD research capabilities at Maryland can be tailored to complement in-house technology at primes for risk reduction