STAFF SUMMARY SHEET

	TO	ACTION	SIGNATURE (Surname), GRADE AND DATE		TO	ACTION	SIGNATURE (Surname), GRADE AND DATE
1	DFAN	sig		6			
2	DFER	approve	Brent A Richardson, Col 28 Mar 2012	7			
3	DFAN	action	(Author /Originator)	8			
4				9			
5				10			

SURNAME OF ACTION OFFICER AND GRADE	SYMBOL	PHONE	TYPIST'S INITIALS	SUSPENSE DATE
Dr. Mehdi Ghoreyshi	DFAN	333-3154	bar	20120328

SUBJECT

Clearance for Material for Public Release USAFA-DF-PA- 209

DATE

28 Mar 2012

SUMMARY

1. PURPOSE. To provide security and policy review on the document at Tab 1 prior to release to the public.

2. BACKGROUND.
Authors: Dr. Mehdi Ghoreyshi, DFAN

Title: Reduced-Order Aerodynamic Loads Modeling of Maneuvering Aircraft

Circle one: Paper

Check all that apply (For Communications Purposes):

[] CRADA (Cooperative Research and Development Agreement) exists

[] Photo/ Video Opportunities [] STEM-outreach Related [] New Invention/ Discovery/ Patent

Description:

Release Information: To be submitted to "The Postdoc," newsletter of the National Academies' Research Associateship Program

Previous Clearance information: Content previously cleared for presentation at AIAA conferences

Recommended Distribution Statement: Distribution A: approved for public release, distribution unlimited

3. DISCUSSION. N/A

4. RECOMMENDATION. Approve for public release.

(signature)
Mehdi Ghoreyshi, PhD
NRC Research Associate at USAFA/DFAN

Reduced-Order Aerodynamic Loads Modeling of Maneuvering Aircraft

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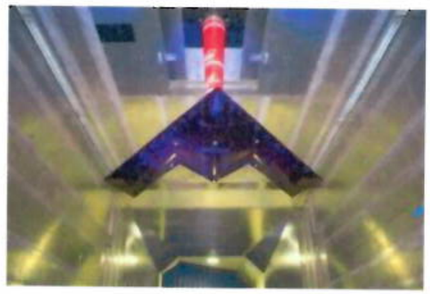
The prediction of aerodynamic loads is still a challenging engineering issue for military aircraft designers. Unsteadiness in the flow can lead to uncommanded motion and uncontrollable departure in flight testing. Despite their greatest efforts using the best available predictive capabilities, nearly every major fighter program since 1960 has had costly nonlinear aerodynamic or fluid-structure interaction issues that were not discovered until flight testing. Currently, the use of computational fluid dynamics (CFD) solutions is considered the state of the art in modeling unsteady nonlinear flow physics and offers an early and improved understanding and prediction of aircraft aerodynamic characteristics. Specifically, significant progress has been made by the US Air Force Academy (USAFA) and others in demonstrating the ability of Unsteady Reynolds Averaged Navier-Stokes (URANS) and Delayed Detached Eddy Simulation (DDES) approaches to accurately predict the forces and moments on aircraft maneuvering at the edge of the flight envelope. With the advanced computing techniques, one straightforward way to calculate unsteady aerodynamics forces and moments of a maneuvering aircraft is to develop a full-order mathematical model based on direct solution of discretized Navier-Stokes equations coupled with the dynamic equations governing the aircraft motion. However, a full-order model for Stability & Control (S&C) analysis is computationally very expensive approach since such a model needs a large number of coupled computations for different values of motion frequency and amplitude. An alternative approach to solving the full-order model is to develop a Reduced Order Model (ROM) that seeks to approximate CFD results by extracting information from a limited number of full-order simulations.

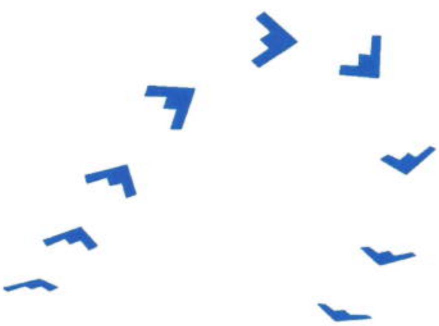
Dr Ghoreyshi's research at USAFA, under the guidance of Prof. Russell Cummings, focuses on the development of ROMs using CFD to make timely progress in predicting and modeling unsteady loads of a maneuvering aircraft. The developed ROMs are based on indicial functions and Radial Basis Functions for different configurations. A linear ROM was created using indicial type CFD calculations (URANS) and used for predictions in order to check the validity of the ROMs for the SACCON UCAV undergoing a lazy-eight maneuver (Fig. 1). The comparisons between the created ROM with the full-order model show good agreement in lift, pitch moment, and side force. The small discrepancies at high angles of attack are very likely due to the linear assumptions in the ROM, which will be addressed in the next phase of work. Note that the computational grid has around 13M cells and the cost of generating the full-order model is approximately 50,000 CPU hours using 512 processors. Once the ROM is created, the aerodynamic loads for maneuvers can be predicted on the order of a few seconds.

Dr. Mehdi Ghoreyshi, NRC Research Associate at the US Air Force Academy

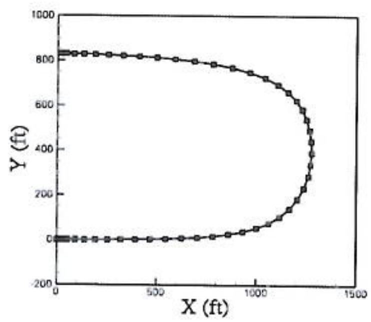
Also, the X-31 fighter undergoing pitching at transonic speeds for three different training maneuvers has been investigated. All maneuvers ran for 2.4 seconds and started from a steady-state solution. The aircraft responses to these maneuvers were generated using URANS equations. The cost of generating each response is around 138 wall-clock hours using 256 processors (2.3 GHz) for a half geometry mesh with 11.7 M cells. A ROM is created using Radial Basis Functions and was tested for prediction of a pitching motion at transonic speeds (Fig. 2). The results show that the predicted ROM values agree well with the full-order solution, with the ROM based on the Schroeder maneuver showing better accuracy than models based on the chirp and spiral maneuvers. Future work includes development of methods to select the best training maneuver for ROM construction in the frequency/amplitude/Mac/altitude space.



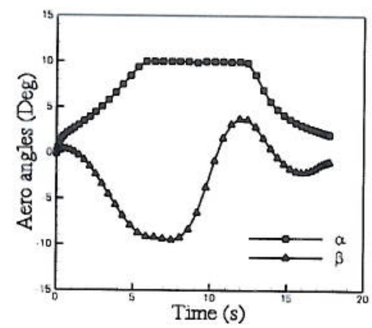
a) **SACCON UCAV**



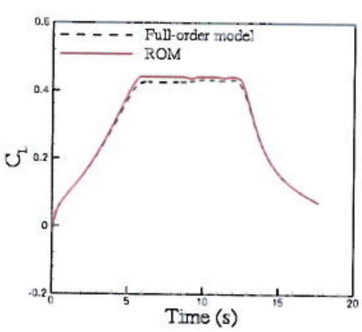
d) **Lazy-Eight maneuver**



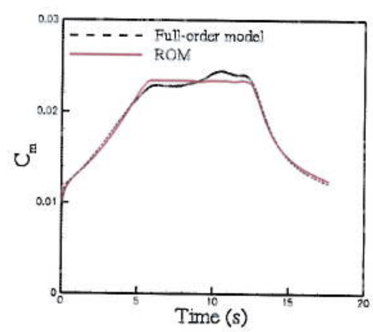
c) **Ground trajectory**



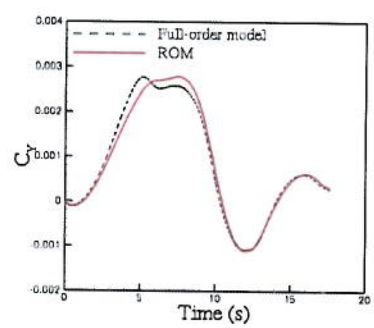
b) **Aerodynamic angles**



f) **Lift coefficient**



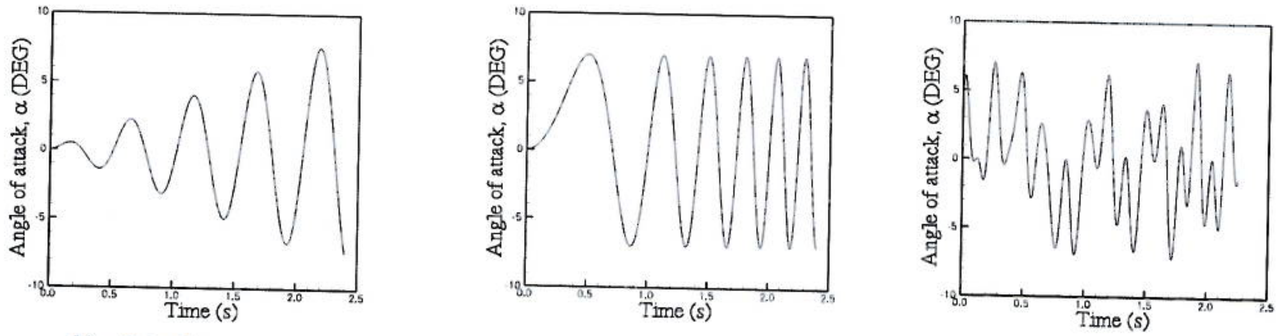
g) **Pitch moment coefficient**



e) **Side-force coefficient**

Figure 1: Reduced order modeling of SACCON Lazy-8 maneuver.

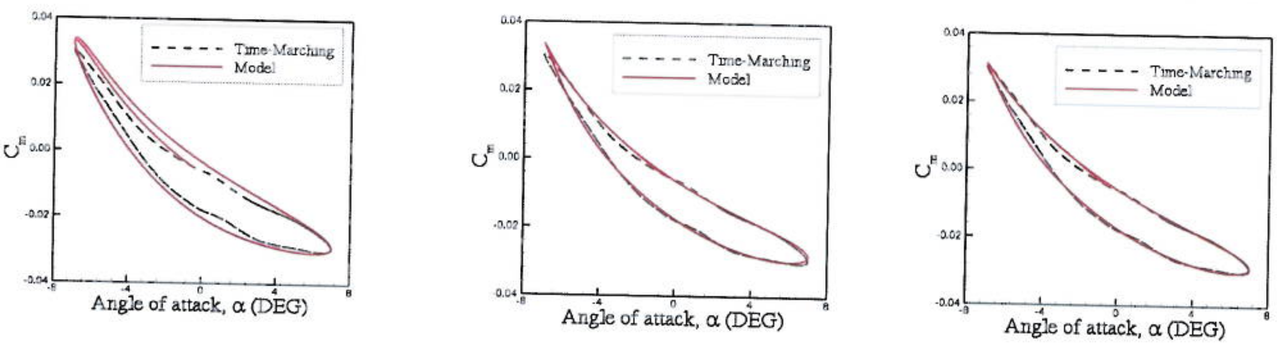
a) X-31 fighter



b) Spiral maneuver

d) Chirp maneuver

c) Schroeder maneuver



g) ROM prediction using Spiral

f) ROM prediction using Chirp

e) ROM prediction using Schroeder

Figure 2: RBF reduced order modeling of X-31 fighter- Training maneuvers are Spiral, Chrip, and Schroeder. The flow conditions are: M=0.9 and Re = $2x10^6$.

Chirp