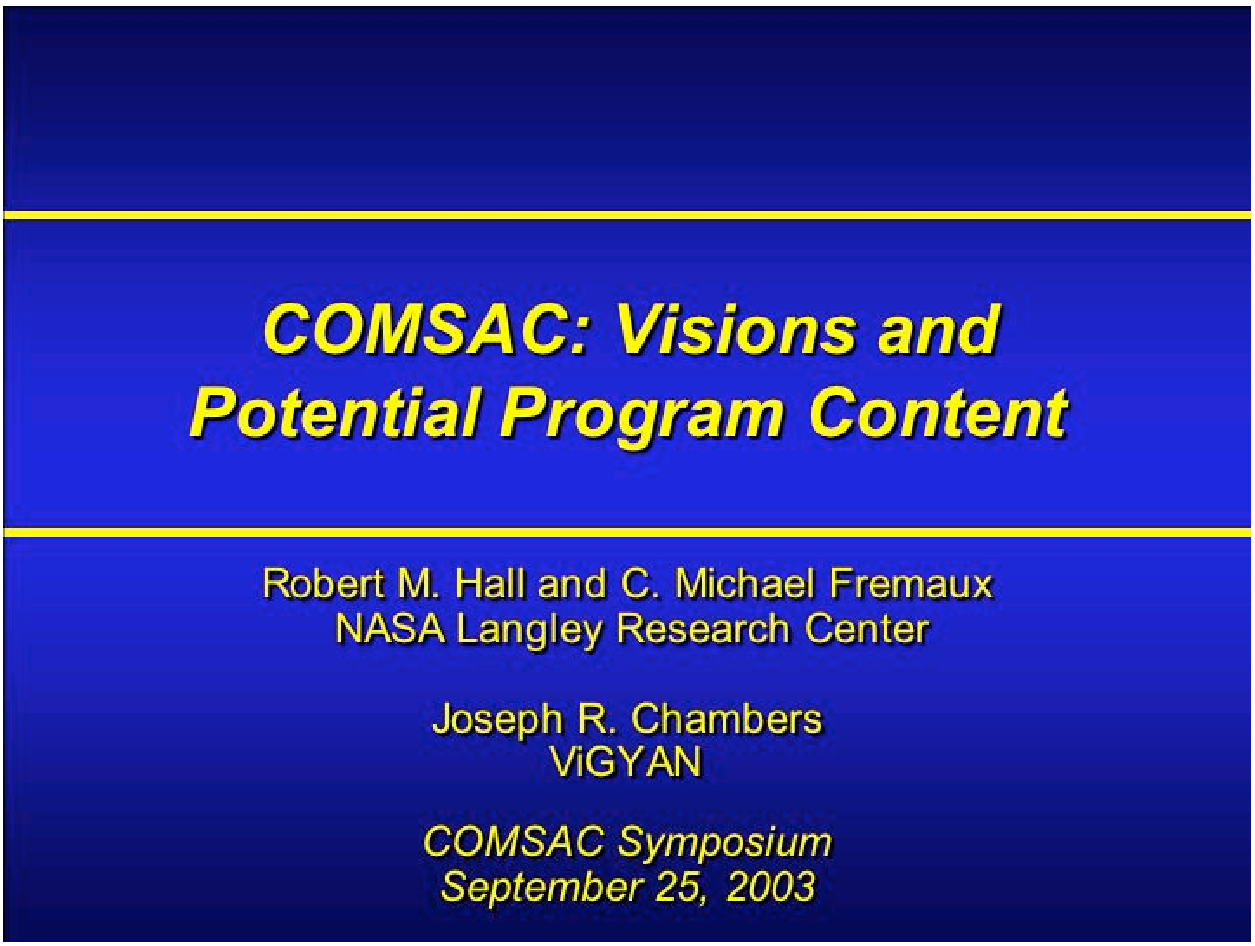
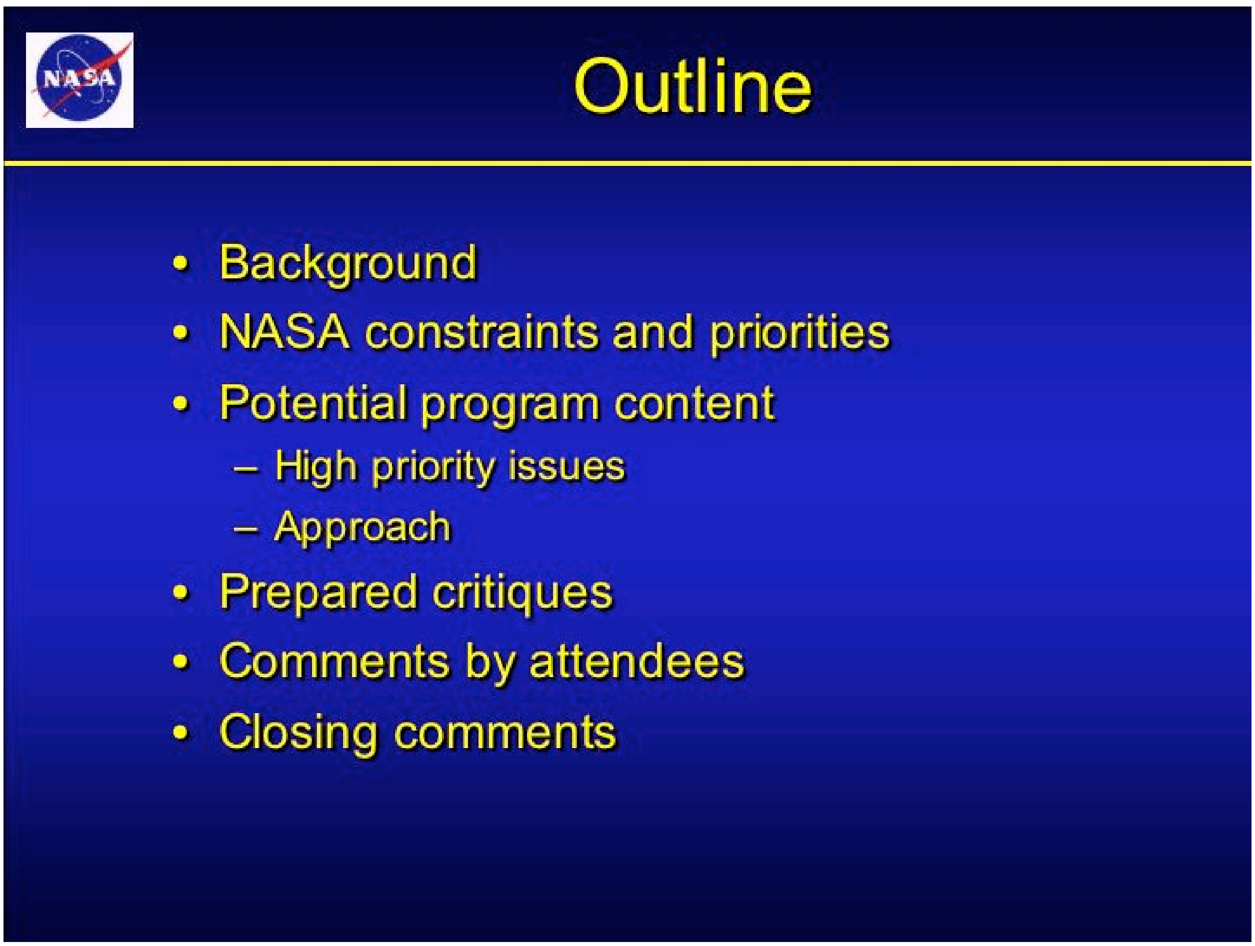
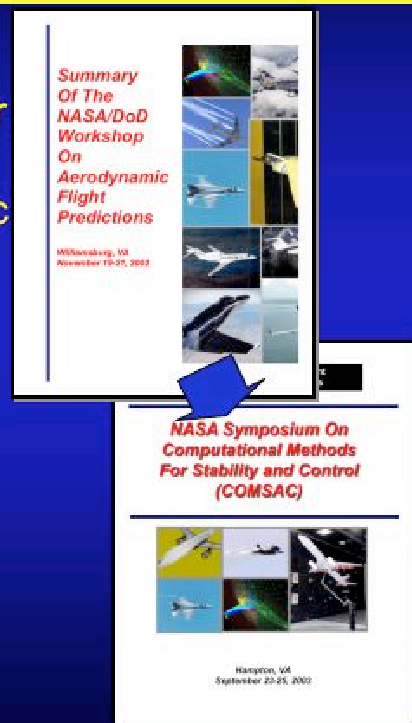
Intent of this talk is to present the S&C priorities as seen by the Langley team. No roadmaps or 5 year plans will be presented. We are actively soliciting your feedback, your ideas, and your help in building and executing this program.




Outline
• Background
• NASA constraints and priorities
• Potential program content
– High priority issues
– Approach
• Prepared critiques
• Comments by attendees
• Closing comments

Background

- Promise of CFD highlighted by Abrupt Wing Stall program and other activities
- Needs apparent during Aerodynamic Flight Prediction Workshop
  - Williamsburg, VA, Nov. 19-21, 2002
- Industry/DOD tour
  - NAVAIR 2/11/03
  - Boeing Seattle 4/28/03
  - Lockheed-Martin Ft. Worth 4/29/03
  - Boeing St. Louis 4/30/03
  - Lockheed-Martin Marietta 5/2/03
  - AFRL 6/5/03
- COMSAC Symposium



Preliminary Feedback

- Much skepticism on CFD applications to S&C (both S&C and CFD communities)
  - Considerable “wait & see” attitude
- Only “9-1-1” activities in most organizations
- Limitations of current tools acknowledged
- Some potential collaborative efforts identified
- NASA encouraged to continue planning

NASA Constraints & Priorities

- NASA guidance for research on military configurations
  - OMB: Cooperative work with DOD encouraged when there is a dual civil/military application
- NASA focus is generally on civil configurations
- COMSAC planning continues to identify civil and military issues

COMSAC Objective

- Accelerate the application, validation, and focused development of CFD methodology to S&C aerodynamic predictions and analyses
- Payoffs:
  - Better understanding & control of flow physics
  - Reduced and focused wind-tunnel and flight tests
  - Risk reduction while reducing costs
    - Fewer surprises in flight test & certification
    - Minimizes “cut and try” efforts in flight test

COMSAC Team

- Programmatic responsibility: Jim Pittman (EASI lead)
- Former programmatic responsibility: Long Yip
- Technical lead: Bob Hall (S&C, CAB)
- Technical co-lead: Mike Fremaux (S&C, VDB)
- CFD lead: Paul Pao (CAB)
- CFD consultant: Jim Thomas (CMSB)
- S&C: Joe Chambers (Consultant)

COMSAC Team, Concluded

- CFD: Bob Bartels (AB)
- CFD: Bob Biedron (CMSB)
- CFD: Neal Frink (CAB)
- CFD: Farhad Ghaffari (CAB)
- S&C: Larry Green (MDOB)
- S&C: Pat Murphy (DCB)
- S&C: Ray Whipple (VDB)

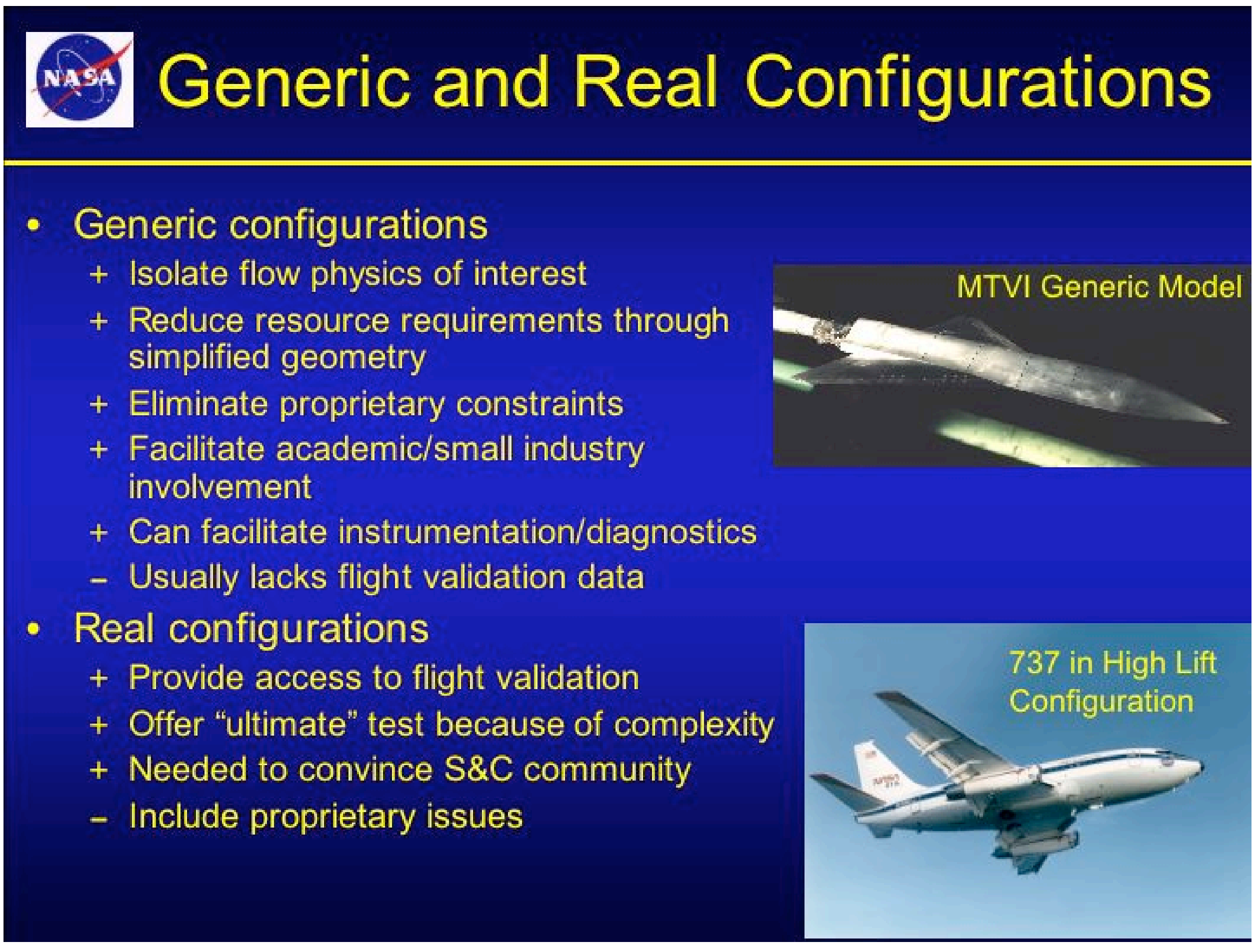
People under Contract or Grant:

- CFD: Jim Forsythe, COBALT Solutions
- CFD: Case van Dam, UC Davis

COMSAC CFD Strategy

- Establish S&C “benchmark” cases to calibrate & validate computational tools for most pressing problems
- If wind tunnel or flight data are insufficient, conduct required experiments
- Major thrust is to take off-the-shelf RANS or RANS+ codes and apply
- Codes MUST be run “blind.” Data revealed after predictions.
- If codes are inadequate, **focused** code development for S&C applications will be pursued
- Secondary thrust is to assess accuracy of reduced-physics, engineering codes
- Balance between generic and specific applications

A program like COMSAC will have to have a balance of generic and real configurations.



COMSAC
General Issues

- Streamlined CFD analysis process is overarching need
  - Automated
  - User friendly
  - Robust
- Another technology issue is being able to simulate laminar separation bubble and turbulent reattachment
- How valuable are correct answers?
  - RANS vs RANS+ (DES)

Prioritized S&C Issues
NASA Perspective

- High lift S&C
- Dynamic derivatives
- Wing stall progression, unsteadiness, and hysteresis
- Flow control devices
- Rn and M_∞ effects
- Hinge moments, loads
- Aeroelastic effects
- Cruise S&C
- High-α or upset conditions
- Accurate predictions for trim
- Interactions between closely coupled control surfaces
- Ground effects
- Propulsion-induced effects
- Wind-tunnel operational effects

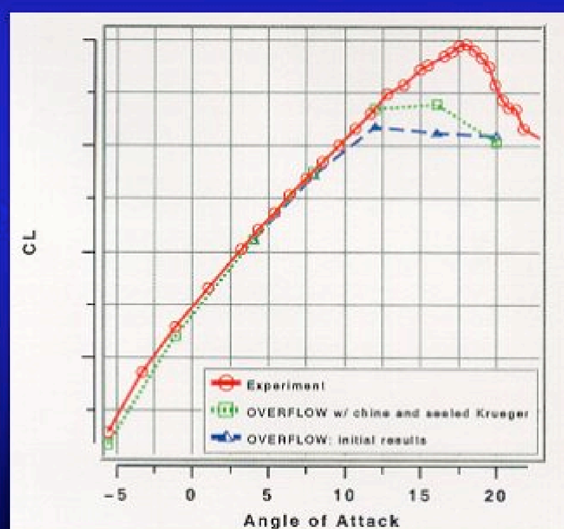
Prioritized S&C Issues
Mentioned in Symposium

- Longitudinal stability (including C_{m_o}) (Donaldson)
- High-α lift curve definition (Killingsworth)
- Prioritized list by Bogue
- C_m as a function of α for DC-9 and F-16 (Mason)

High Lift S&C for Civil Aircraft
The Challenge

- Why
  - High lift phase is critical to aircraft operations
  - SOA for CFD applied to high lift is similar to that for performance problems 10 or 15 years ago
- Example

$C_{L,max}$ and local slopes are typically missed



Data courtesy of David Bogue. Citation is Rogers, Roth, Cao, Slotnick et al., "Computation of Viscous Flow for a Boeing 777 Aircraft in Landing Configuration," AIAA 2000-4221

High Lift S&C for Civil Aircraft
Notional Approach

- Potential barriers
  - Complex geometry drives gridding requirements
  - Flap elements dominated by transition and separation issues, gap flows, multi-element interactions
  - Turbulence modeling
  - Role of transition, laminar separation bubbles
- Near-term plan
  - Identify and assess data bases
  - Extend Ground-to-Flight Scaling tests of a Boeing configuration to sideslip
  - Assess 3 or 4 code systems against best available data
    - Flow physics
    - Grid adaptation strategies
    - Algorithms and turbulence modeling
  - Decision point/milestone--are additional data required?
  - Workshop in 2 years time to report out and direct direction/needs

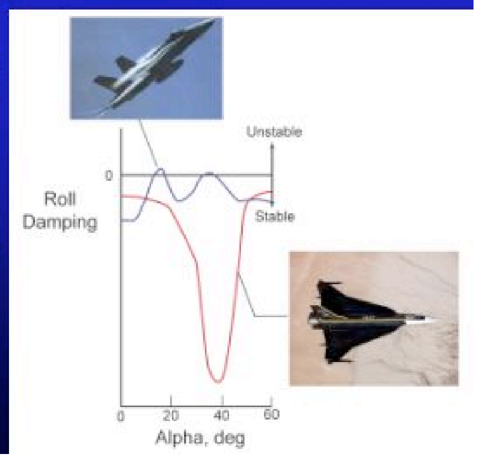
Trap Wing in14x22

777 in NTF

Dynamic Derivatives
The Challenge

- Why
  - CFD needed to augment relatively poor predictive capability
    - Limited experimental capability
    - Simplified analysis methods
  - Damping derivatives are critical
    - Predicting flying qualities near stall
    - Large impact on flight control systems
- Example

Large differences in damping between configurations can result from differences in leading edge sweep and time lags in vortical flow development



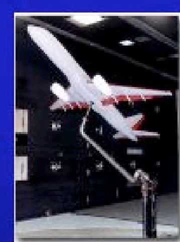
Dynamic Derivatives
Notional Approach

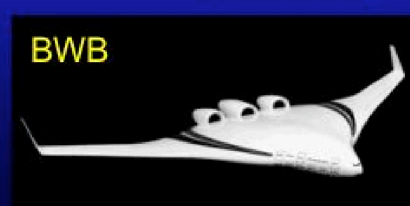
- Potential Barriers
  - Resource requirements for unsteady calculations
  - Calibration data
  - Nonlinearities of derivatives

F/A-18C on Free-to-Roll (FTR) Test Rig during AWS Testing

- Plan
  - Identify suitable experimental data bases
  - Extend FTR testing to 757 and BWB to complement existing 757 forced oscillation (FO) data base
  - Simulate both FTR and FO motions of 757 and BWB with computational tools
  - Exercise time-accurate codes to simulate unique motions to measure true α and β dot terms

757 in Langley 14 x 22

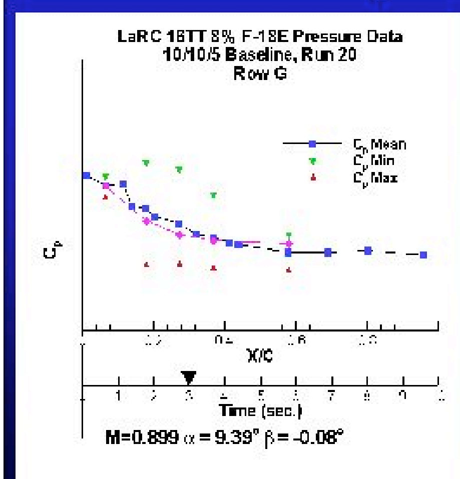




BWB

Stall Progression, Unsteadiness and Hysteresis--The Challenge

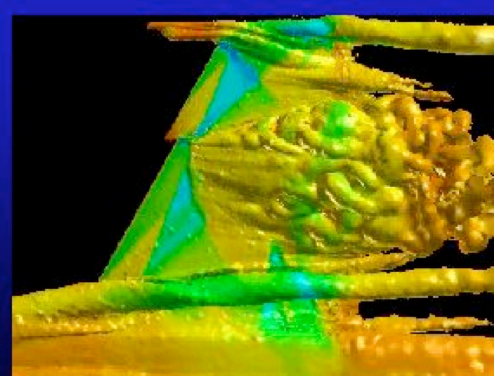
- Why
  - Stall progression characterization is critical to predicting stability near wing stall
  - Shock unsteadiness integral aspect of transonic stall
  - Interpretation of hysteresis not understood (challenge given by Dale Lorincz)



Note large shock movement during stall process for F/A-18E

Exp by Schuster

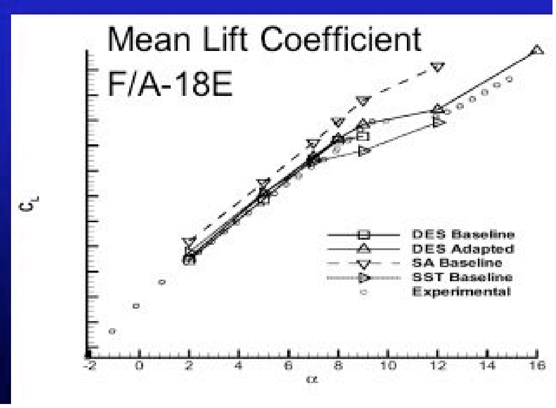
CFD by Forsythe



Stall Progression, Unsteadiness and Hysteresis--Notional Approach

- Potential Barriers
  - Resource requirements for unsteady calculations
  - Bistable flow states
  - Turbulence models
  - DES vs RANS
  - Grid refinement strategy for DES
- Plan
  - Summarize and collect data
  - While stall progression addressed in AWS program, not tackled with S&C in mind
  - Continue to study impact of hysteresis
  - Conduct workshop in 2 years

Time-averaged values of unsteady solutions significantly improve correlation with data



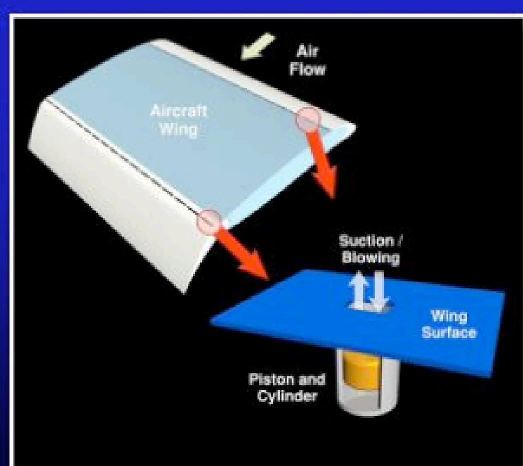
Passive and Active Flow Control
The Challenge

- Why
  - Passive devices, such as vortex generators (VGs) and vortilons, are important solutions to flow control problems
  - Subscale development of VGs is problematic
  - Successful CFD characterization could reduce risk
  - Challenges more severe with unsteady, active flow control concepts
- Example

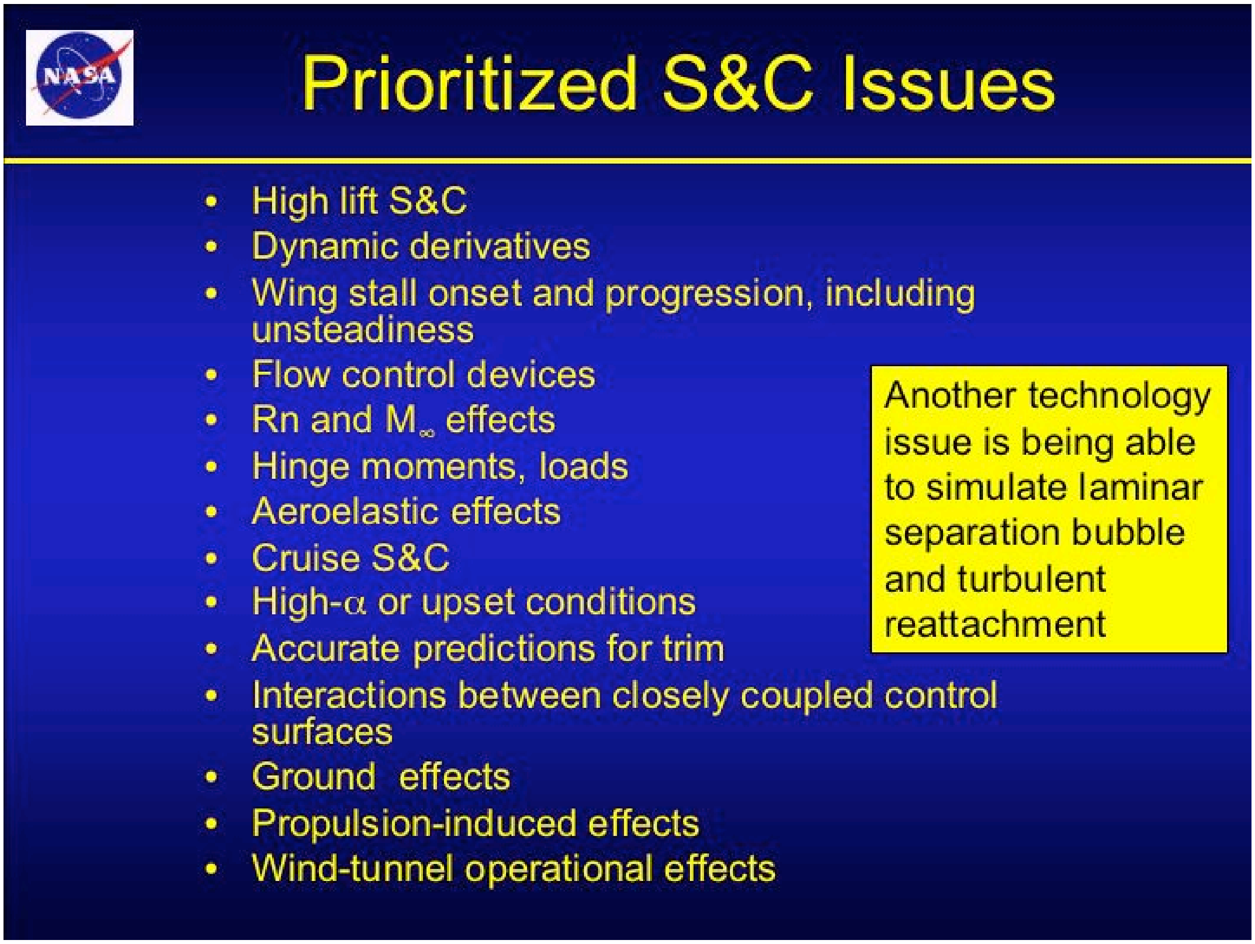
VGs and vortilon on prototype AV-8B

Passive and Active Flow Control Notional Approach

- Potential barriers
  - Gridding requirements--complex
  - Turbulence modeling
  - Time accurate solution requirements
- Near-term plan with passive flow control
  - Capitalize on Boeing work
  - Identify and assess data bases for passive flow control devices
  - Need to examine impact of rates and sideslip
  - Assess gridding requirements
- Far-term plan--address active flow control characterization
  - CFD should lead in application strategy
  - Benchmark/Validation workshop in 04 already planned with Langley Time Accurate Program



The list is our best shot of what we view as important while we understand that there are a myriad of candidates. If an issue that is important to you is not reflected in the list, let us know!



Summary of COMSAC Vision

- Have shared our philosophy
  - CFD maturity is pushing the application toward S&C, which could readily use calibrated CFD tools
  - Tackling the problem will take generic and realistic, flight configurations
  - For CFD to have an impact, it must demonstrate its predictive capability against “benchmark” cases from both the shallow and deep ends of the pool
  - Workshops to discuss specific “challenge”areas
- Have shared our vision of important S&C issues

Prepared Critiques

- NASA's vision of COMSAC options forwarded to reviewers on Tuesday
  - Pradeep Raj, Lockheed Martin
  - John Clark, NAVAIR
  - Doug Ball, Boeing Commercial
- Reviewers will follow me
- Comments and critique then taken from general audience

Open Discussion

- Opportunity to philosophize, comment, and critique what has been said
- Also seeking feedback via post-meeting evaluation forms

Closing Comments

- CFD technology and computational resources are poised to make inroads into the S&C arena
  - Can fill in the experimental gaps
  - Will be a natural complement to experiment
  - Expected to significantly reduce amount of wind tunnel and flight testing
  - Large impact on risk reduction
- Challenges are many
- Objective of COMSAC is to accelerate and focus national efforts in this area