Focus Session on Simulation at Aeronautics Test Facilities

October 15, 2014
Questions to be addressed during presentation

- How has the ability to do increasingly accurate modeling and simulation (M&S) changed the way aeronautics test and evaluation (T&E) facilities are used? How has it changed the way we do flight test?

- From a T&E standpoint, are U.S. M&S capabilities sufficiently mature and reliable? How well are NASA facilities meeting the needs of industry regarding advanced M&S capabilities for aeronautics T&E?

- How well is NASA working with other government entities and academia to enhance M&S capabilities for aeronautics T&E?

Background for presentation

- This presentation will treat M&S as synonymous with CFD and T&E as synonymous with ground test facilities, specifically wind tunnels.
Utilization of CFD has become prevalent on programs primarily because of improved accuracy and efficiency:

- Algorithm improvements
- Turbulence model improvements
- Availability of increased computational power is a key enabler:
  - Enables faster turn-around
  - Enables higher-fidelity modeling via discretization refinement
  - Enables database development, i.e. population of large run matrices

Example for a similar launch vehicle configuration:

- 1991 – 0.5M grid point model, 30 days/case, 1 case at a time, UCLA supercomputer
- 2014 – 10M grid point model, 45 minutes/case, 25 cases at a time, in-house Linux cluster
  - Improved accuracy based on grid resolution enhancement of 20x, plus improved accuracy due to algorithm and turbulence model improvements
  - Improved efficiency of 480000x per grid point, or 24000x per solution
Trend is to introduce high-fidelity CFD methods in early design cycles along with a corresponding reduction in wind tunnel testing

- Geometry is often in a state of flux which makes computational approach more appealing
- Fabrication of wind tunnel models and availability of test facilities are often pacing items during early, short-duration design cycles
- Access to rapid and accurate CFD methods enables reduction in design cycle duration and reduced reliance on third-party schedules (WT model vendors, WT test facilities, etc)

Heavy reliance on wind tunnel testing (along with CFD) for final design and verification activities

- Desire is to reduce reliance on wind tunnel testing further, but is this feasible in the near term?
For some configurations, M&S capabilities are sufficiently mature and reliable to reduce reliance on wind tunnel testing.

However, this is not true for every configuration, as indicated on the next slide.

M&S capabilities often fall short when flow separation, boundary layer transition, turbulent mixing, etc., are 1st-order contributors to the parameters of interest.

Users of data must understand limitations of M&S methods:

- Improper reliance on poor quality M&S data can have severe adverse impacts to a program:
  - Design issues not identified until late in the design or verification cycles cause significant cost and schedule issues.

- Ground test facilities (wind tunnels) are required to develop the “truth” data needed to gage adequacy of M&S methods.
  - Users must also understand limitations of ground test data.
M&S Maturity and Reliability (cont’d)

Space Access Configuration #1

Space Access Configuration #2

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Challenge Problems

Boeing Defense, Space & Security (BDS)

- CFD methods are relatively immature for tackling the most difficult problems often encountered
- One example – massive flow separation leading to aerodynamics, aeroacoustics, and/or buffet issues
  - The #1 program risk on several recent high-profile development programs
  - Steady and unsteady RANS modeling is inappropriate and insufficiently accurate for these simulations
    - Hybrid models, such as DDES, offer an improvement over URANS, but accuracy remains marginal
  - Unsteady CFD simulations on full-scale vehicle platforms with sufficient grid resolution to capture the flow physics remain “grand challenge” problems
    - These simulations are performed routinely with less-than-desired grid resolution
      - Consume tremendous computational resources and calendar time
      - Data accuracy is typically good enough for trends, insufficiently accurate for design
      - Does not even scratch the surface in terms of database coverage (Mach / alpha / beta)
  - In spite of these deficiencies, CFD can be used to help resolve these types of issues
    - Aero shape optimization to eliminate massive flow separation
    - Development of aerodynamic devices for flow control
- Other challenge examples – boundary layer transition, turbulent mixing and chemical kinetics, etc.
- Reliance on test facilities will be required for the foreseeable future to address these challenge problems
  - Provide final design and verification datasets prior to flight
  - Provide high-quality validation datasets to support development of improved computational models
NASA Collaboration with Government and Academia

Branches of the DoD are collaborating in the development of the next generation of computational tools for aerospace application

- CREATE-AV Project
  - Full coordination across DoD to produce next generation of physics-based computational methods for DoD acquisition engineering
  - Significant investment commitments by DoD for a long-duration computational sciences development effort

Computational science development efforts within NASA appear to be less coordinated across the agency

- Per recommendations of the recent NASA-funded Vision 2030 CFD study report prepared by Boeing-led team of CFD experts, a long-term base research and development effort coordinated across the agency must be initiated to address CFD technology gaps and enhance CFD capabilities
- Increased collaboration between NASA and DoD would also be beneficial

*CREATE-AV images obtained from publicly released CREATE-AV presentation
Sustained and coordinated investments in the computational sciences will continue to pay huge dividends

- Efficiency and accuracy improvements continue to be realized
  - Automated solution adaptive gridding
  - Improved algorithms and turbulence / transition modeling
  - Improved aero shape optimization and MDAO methods
  - Reduction in reliance on “CFD expert” to ensure quality – enhancing the availability of reliable and accurate computational methods

Wind tunnel facility advancements should remain high priority

- A couple of examples from recent aeroacoustics test experiences
  - Fast Pressure Sensitive Paint (Fast PSP) capability promises to enable characterization of high-frequency fluctuating pressures (aeroacoustics) over the surface with greatly improved resolution relative to models instrumented with pressure transducers only
  - Improved data acquisition systems allow for collection of large volumes of higher-frequency data required to characterize these environments

The few remaining wind tunnel test facilities are national assets, and continued advancement of WT test technologies is critical for the continued success of the US aerospace industry