Introduction of First Low Boom Prediction Workshop

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An introduction to the first low boom prediction workshop is presented. The workshop objective will be to assess the state of the art for using computational fluid dynamics to predict near-field pressure signatures needed for accurate sonic boom propagations. Workshop participants will be supplied with 3 models, analysis of two will be required and the third optional. The models vary from a simple body of revolution to a complex full aircraft configuration with flow through nacelles. Participants will be supplied with computational meshes suitable for Euler analysis. Wind tunnel data will also be made available before the workshop for comparison with participant generated computational results. At the conclusion of the workshop, areas will be identified which require additional research and development to accurately predict low sonic boom near-field signatures.

Nomenclature

AIAA	American Institute of Aeronautics and Astronautics
BOR	body of revolution
CAEP	Committee on Aviation Environmental Protection
CFD	computational fluid dynamics
C_L	lift coefficient
FAA	Federal Aviation Administration
H	distance away from aircraft
NASA	National Aeronautics and Space Administration
SSBD	shaped sonic boom demonstrator
α	angle of attack
ϕ	roll angle

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I. Introduction

Since the Concorde retired at the end of 2003, there has not been a civilian supersonic aircraft. The Concorde was restricted from flying over land supersonically due to FAA and CAEP regulations prohibiting supersonic flight over land in the United States and other countries. This prohibition is due to the environmental impact and community annoyance of the sonic boom created by supersonic flight. The over land restriction severely limited the Concorde's possible routes, thus limiting its economic viability. Many in industry, government, and academia believe that in order to have a commercially viable supersonic civil aircraft, it must not be restricted from flying over land supersonically. In order to achieve supersonic flight over land, the sonic boom must be minimized in order to get the FAA and CAEP regulations to be lifted

Over the last ten years there has been a renewed interest from industry, government and academia on supersonic research to minimize the sonic boom. This is evident from the shaped sonic boom demonstration (SSBD)[1], the Quiet Spike™ flight test[2], the D-Send drop test[3], and most recently the National Aeronautics and Space Administration (NASA) N+2 supersonic validation programs[4,5]. One common link between the programs mentioned is the heavy reliance on computational fluid dynamics (CFD). As computational power steadily increased over the last two decades, CFD has continually become a larger part of the designer's toolbox. The design of a low boom supersonic aircraft will involve extensive use of CFD. In particular, CFD will be used to predict the near-field off body pressures produced by the low boom aircraft. These results will be used in conjunction with other computational methods to predict the ground level sonic boom signatures and assess their acceptability. Over the last several years there has been an increasing focus on identifying the limitations of CFD for high lift[6] and drag prediction[7]. Much of this effort has been coordinated and formalized through the American Institute of Aeronautics and Astronautics (AIAA) sponsored High Lift and Drag prediction workshops. The use of CFD for low boom prediction has been increasing throughout industry, government and academia. The first known attempt to coordinate an assessment of the state of the art for low boom prediction is the Sonic Boom Prediction workshop held at the NASA Fundamental Aeronautics Annual Meeting in 2008[8]. That workshop was limited to NASA participants and mainly NASA codes. The goal of the upcoming workshop is to similarly coordinate an assessment of the state of the art and identify areas requiring additional research and development for low boom prediction. However, this workshop will be open to the general aerospace community. The First AIAA Low Boom Prediction Workshop will take place on Saturday, January 11, 2014 at the 2014 AIAA Science and Technology Forum at the Gaylord National Harbor, National Harbor, Maryland.

II. Objective

The objective of the first low boom prediction workshop is to assess the state of the art for predicting near-field pressure signatures needed for accurate and reliable sonic boom prediction. Comparisons will be made between participant solutions on workshop provided grids. Participants are requested to apply their best practices for computing solution on the provided geometries. There is particular interest in exploring refinement techniques including grid adaptation and alignment with flow characteristics. Impartial comparisons will be made between different solution schemes as well as with available wind tunnel validation data for assessing the state of the art and identifying areas requiring additional research and development.

III. Details

Participants will be required to compare CFD to experimental data to two models on provided Euler meshes at two different distances below the aircraft. Participants can optionally go to farther distances, compare to off track computational results, use their own mesh (Euler or viscous), and/or compare results on a third provided more complex configuration. If a participant develops their own grid they will be required to provide the mesh to the workshop.

The first required model is a Boeing provided body of revolution (BOR)[9] developed as part of the NASA N+2 study in reference 4 This model was tested at NASA Ames 9' x 7' unitary plan wind tunnel. A picture of the BOR is shown in figure 1. The model is 8 inches long. STEP files, Euler unstructured and structured meshes will be provided for this model. In addition, on-track wind tunnel data will be provided below the BOR at distances between 26 inches and 34 inches. Table 1 provides a list of run conditions and distances below the aircraft that wind tunnel data is available.

The second required model is the NASA 69 delta wing-body[10]. This model is a 0.65% scale and was first tested in the early 70's at the NASA Ames 9' x 7' unitary plan wind tunnel and recently retested by Lockheed Martin in the same facility, but with a new system[11] to measure off body pressures. A schematic of the delta wing-body is shown in figure 2. The model is a 17.52 inches long. STEP files, Euler unstructured and structured meshes will be provided for this model as well. In addition, on-track wind tunnel data will be provided below the delta wing at distances between 21.2 inches and 31.8 inches. Some off-track data will be available for this model as well at several distances below the aircraft. Table 2 provides a list of run conditions and distances below the aircraft that wind tunnel data is available.

The third and optional model is a Lockheed provided full aircraft configuration[12] developed as part of the NASA N+2 study in reference 5. This is a 0.8% scale model and comprises a fuselage, wing, twin V-tails, and flow through nacelles. This model was also tested at the NASA Ames 9' x 7' unitary plan wind tunnel. A picture of the 22.396 inches long model in the 9' x 7' wind tunnel is shown in figure 3. STEP files and Euler unstructured meshes will be provided for this model. In addition, on-track wind tunnel data will be provided below the full configuration at distances between 19.7 inches and 69.6 inches. Some off-track data will be available for this model as well at several distances below the aircraft. Table 3 provides a list of run conditions and distances below the aircraft that wind tunnel data is available.

Participants are highly encouraged to use their best gridding practices to generate their own meshes in addition to the supplied meshes. Grid alignment techniques, mesh adaptation, and any other novel practices are of particular interest. Also, viscous analysis is encouraged in addition to the required Euler analysis to assess the viscous effects on the CFD to wind tunnel comparisons. Lastly, participants are highly encouraged to test the limits of their solvers and/or gridding techniques to see how far below the aircraft they can reliably predict a pressure signal for one or more of the configurations.

Further details of the low boom prediction workshop can also be found at: http://lbpw.larc.nasa.gov. This website will serve to subsequently communicate information and details about the workshop to interested parties. Participants will also be able to download geometries and wind tunnel data from this website, email questions to the committee and other participants.

VI. Conclusion

Computational tools will play a big part in trying to make acceptably quiet supersonic travel over land a reality. The use of CFD to predict off body pressures must be assessed properly to understand its limitations. Drag and high lift prediction workshops have been enhancing the state of the art for high lift and drag prediction for several years. The goal of the first low boom prediction workshop is to assess the state of the art and identify areas requiring additional research and development for low boom prediction. The organizing committee hopes this is the first of many workshops to enhance the state of the art for low boom prediction.

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References

1. Graham, D., Dahlin, J., Meredith, K., and Vadnais, J.: *Aerodynamic Design of Shaped Sonic Boom Demonstration Aircraft*, AIAA 2005-0008, 2005.
2. Howe, D. C., Waithe, K. A., and Haering, E. A.: *Quiet Spike™ Near-Field Flight Test Pressure Measurements with Computational Fluid Dynamics Comparisons*, AIAA 2008-0128, January 2008.
3. *http://www.apg.jaxa.jp/eng/research/dsend/ds-project.html*
4. Magee, T., Adamson, E.: *Boeing N+2 Low-Boom Design and Validation Phase I Summary,* NASA Fundamental Aeronautics Technical Conference, March 13-15, 2012.
5. Morgenstern, J.: *NASA N+2 Supersonic Validations Phase I Accomplishments,* NASA Fundamental Aeronautics Technical Conference, March 13-15, 2012.
6. *http://hiliftpw.larc.nasa.gov*
7. *http://aaac.larc.nasa.gov/tsab/cfdlarc/aiaa-dpw*

8. Park, M. A., Aftosmis, M. J., Campbell, R. L., Carter, M. B., Cliff, S. E., Bangert, L.: *Summary of the 2008 NASA Fundamental Aeronautics Program Sonic Boom Prediction Workshop*, 51st AIAA Aerospace Sciences Meeting, American Institute of Aeronautics and Astronautics, Reston, VA (Submitted for publication).
9. Magee, T.: *Computer Experimental Validations of a Low Boom Aircraft Design*, 51st AIAA Aerospace Sciences Meeting, American Institute of Aeronautics and Astronautics, Reston, VA (Submitted for publication).
10. Hunton, L. W., Hicks, R. M., Mendoza, J. P.: *Some Effects of Wing Planform on Sonic Boom*, NASA TN D-7160, 1973.
11. Morgenstern, J.: *How to Accurately Measure Low Sonic Boom in Supersonic Wind Tunnels*, AIAA 2012-3215, 2012.
12. Morgenstern, J.: *Full Configuration Low Boom Model and Grids for 2014 Sonic Boom Prediction Workshop*, 51st AIAA Aerospace Sciences Meeting, American Institute of Aeronautics and Astronautics, Reston, VA (Submitted for publication).

Figures and Tables

Figure 1. Picture of Boeing body of revolution

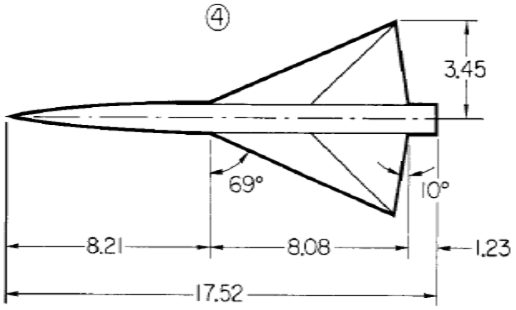

Figure 2. Schematic of 69° delta wing-body configuration.

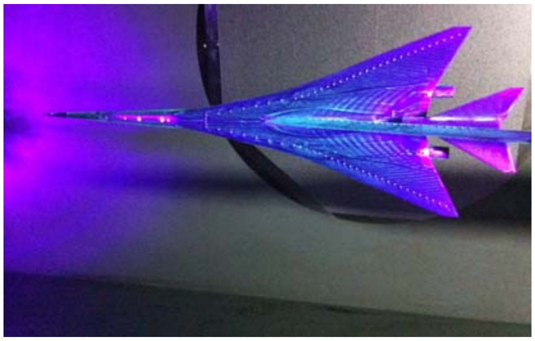

Figure 3. Picture of Lockheed full configuration

Mach	α (deg)	H (inches)
1.6	0	26
1.6	0	30
1.6	0	34

Table 1. Run conditions for BOR and extracted distances (H) that wind tunnel data is available.

Mach	α (deg)	C_L	ϕ (deg)	H (inches)
1.7	0	0	0	31.8
1.7	0	0	0	24.8
1.7	0	0	0	21.2
1.7	2.079	0.08	0	31.8
1.7	2.079	0.08	0	24.8
1.7	2.079	0.08	0	21.2
1.7	3.588	0.15	0	31.8
1.7	3.588	0.15	0	24.8
1.7	3.588	0.15	0	21.2
1.7	0	0	30	31.8
1.7	0	0	30	24.8
1.7	2.079	0.08	30	31.8
1.7	2.079	0.08	30	24.8
1.7	3.588	0.15	30	31.8
1.7	3.588	0.15	30	24.8
1.7	0	0	60	31.8
1.7	0	0	60	24.8
1.7	2.079	0.08	60	31.8
1.7	2.079	0.08	60	24.8
1.7	3.588	0.15	60	31.8
1.7	3.588	0.15	60	24.8
1.7	0	0	90	31.8
1.7	0	0	90	24.8
1.7	2.079	0.08	90	31.8
1.7	2.079	0.08	90	24.8
1.7	3.588	0.15	90	31.8
1.7	3.588	0.15	90	24.8

Table 2. Run conditions for 69° delta wing-body and extracted distances (H) that wind tunnel data is available.

Mach	α (deg)	C_L	ϕ (deg)	H (inches)
1.6	2.3	0.142	0	100.7
1.6	2.3	0.142	0	69.6
1.6	2.3	0.142	0	59.9
1.6	2.3	0.142	0	51
1.6	2.3	0.142	0	42
1.6	2.3	0.142	0	31.8
1.6	2.3	0.142	0	19.7
1.6	2.3	0.142	10	100.7
1.6	2.3	0.142	10	69.6
1.6	2.3	0.142	10	31.8
1.6	2.3	0.142	20	100.7
1.6	2.3	0.142	20	69.6
1.6	2.3	0.142	20	31.8
1.6	2.3	0.142	30	100.7
1.6	2.3	0.142	30	69.6
1.6	2.3	0.142	30	31.8
1.6	2.3	0.142	40	100.7
1.6	2.3	0.142	40	69.6
1.6	2.3	0.142	40	42
1.6	2.3	0.142	40	31.8
1.6	2.3	0.142	50	100.7
1.6	2.3	0.142	50	69.6
1.6	2.3	0.142	50	31.8
1.6	2.3	0.142	60	100.7
1.6	2.3	0.142	60	69.6
1.6	2.3	0.142	60	31.8
1.6	1.93	0.125	0	31.8
1.6	1.93	0.125	40	31.8

Table 3. Run conditions for Lockheed full configuration and extracted distances (H) that wind tunnel data is available.