Incremental Aerodynamic Coefficient Database for the USA2

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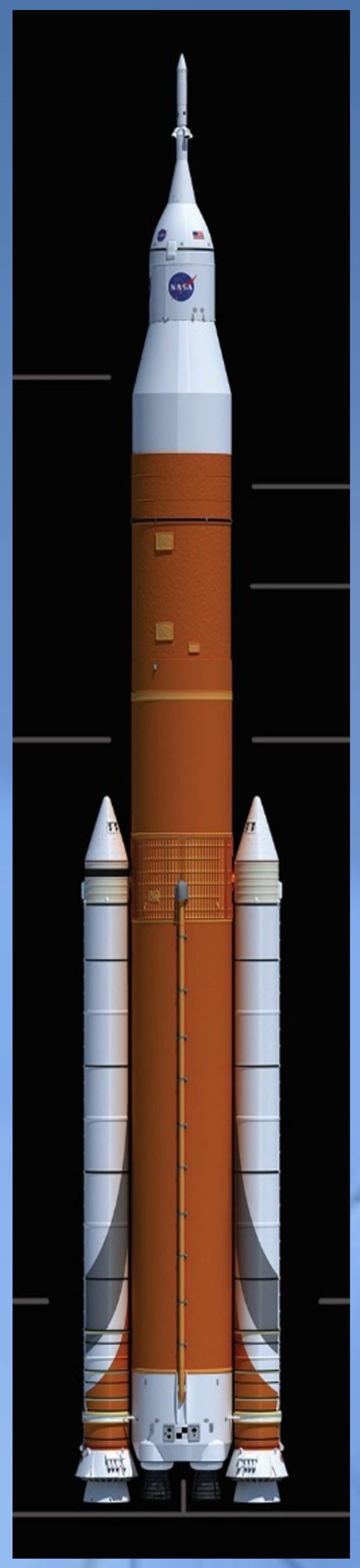
Abstract

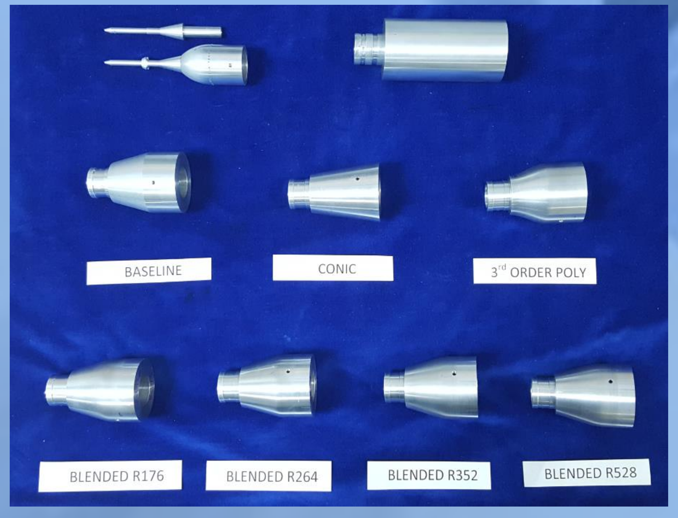
In March through May of 2016, a wind tunnel test was conducted by the Aerosciences Branch (EV33) to visually study the unsteady aerodynamic behavior over multiple transition geometries for the Universal Stage Adapter 2 (USA2) in the MSFC Aerodynamic Research Facility's Trisonic Wind Tunnel (TWT). The purpose of the test was to make a qualitative comparison of the transonic flow field in order to provide a recommended minimum transition radius for manufacturing. Additionally, 6 Degree of Freedom force and moment data for each configuration tested was acquired in order to determine the geometric effects on the longitudinal aerodynamic coefficients (Normal Force, Axial Force, and Pitching Moment). In order to make a quantitative comparison of the aerodynamic effects of the USA2 transition geometry, the aerodynamic coefficient data collected during the test was parsed and incorporated into a database for each USA2 configuration tested. An incremental aerodynamic coefficient database was then developed using the generated databases for each USA2 geometry as a function of Mach number and angle of attack. The final USA2 coefficient increments will be applied to the aerodynamic coefficients of the baseline geometry to adjust the Space Launch System (SLS) integrated launch vehicle force and moment database based on the transition geometry of the USA2.



Objectives

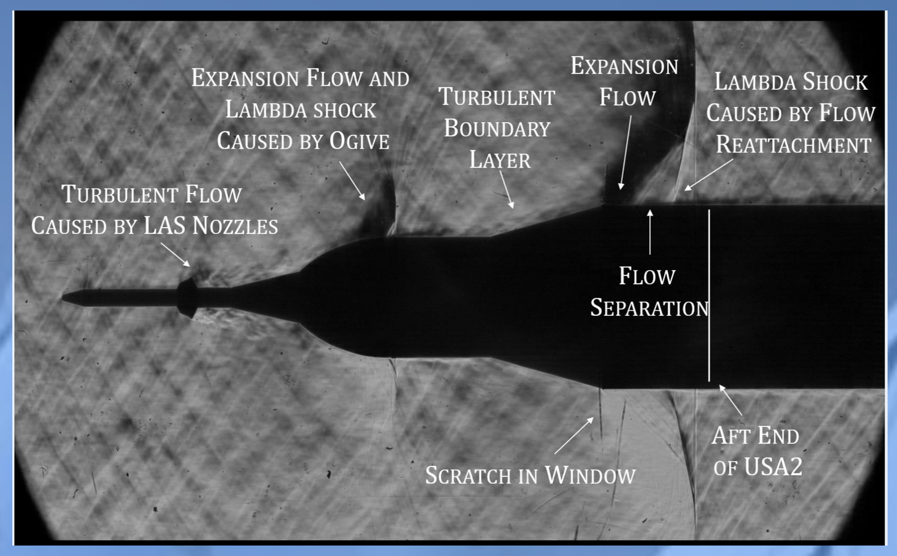
- Develop an incremental aerodynamic coefficient database that will be used to adjust the force and moment coefficients of the Space Launch System (SLS) integrated launch vehicle based on the transition geometry of the Universal Stage Adapter 2.To develop macros in Microsoft Excel in order to accelerate the process of eliminating unused data points and obtaining coefficient data not obtained through testing for certain angles of attack using polynomial interpolation through Excel's "LINEST" function.
- Develop a Macro using Microsoft Excels Visual Basic for Applications (VBA) programming language in order to accelerate the process of parsing the wind tunnel data, eliminating unused data points, and obtaining coefficient data for cardinal angle of attack positions not directly obtained during testing using polynomial interpolation through Excel's "LINEST" function

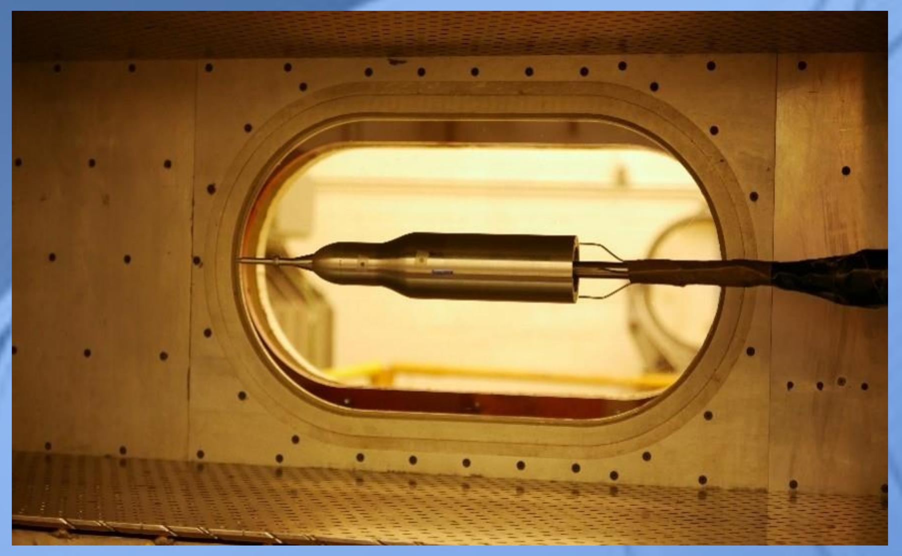
Each of the seven different USA2 geometries tested along with the Launch Abort System (LAS) and center body.



Background

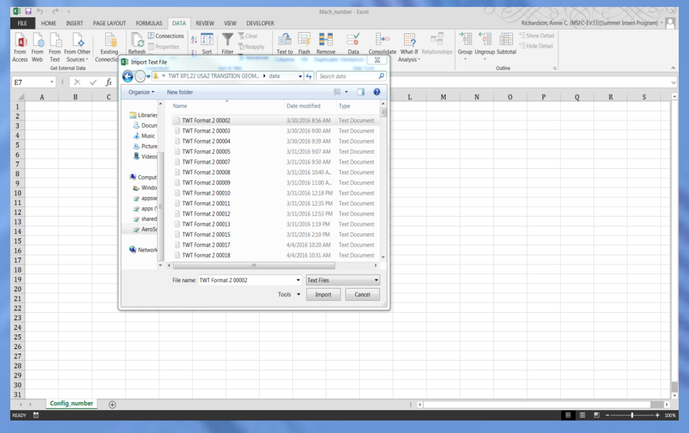
NASA's Space Launch System (SLS) consists of a family of evolvable heavy-lift launch vehicles that will carry cargo and humans beyond low-Earth orbit. Ongoing is a preliminary design cycle for the SLS-28000 block 1b vehicle, during which different Universal Stage Adapter 2 (USA2) geometries are being considered. The USA2 geometry will be chosen based on its manufacturability, structural integrity, and aerodynamic environments. A wind tunnel test conducted between 31 March and 9 May 2016 in the NASA Marshall Space Flight Center (MSFC) Aerodynamic Research Facility (ARF) 14-inch Trisonic Wind Tunnel investigated the transonic flow field around the transition corner of the SLS block 1b crewed launch vehicle USA2. Seven different geometries were tested between ±10° angles of attack and for a Mach number range of 0.8 to 1.3. These geometries include the sharp corner baseline, a third order polynomial spline fit, four blended radii, and an 8° conic. A total of 180 runs were obtained.



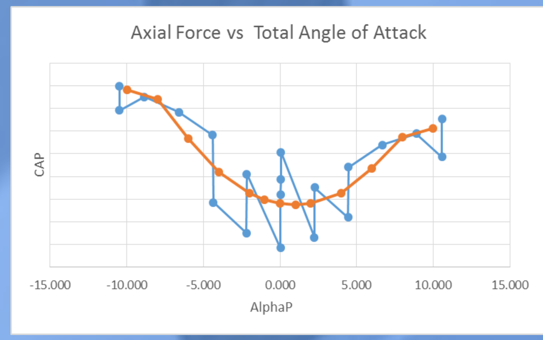


Methodology

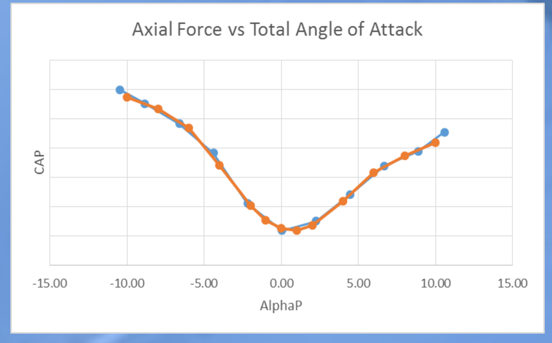
- Develop an efficient macro for importing the raw wind tunnel data text files into a spreadsheet using VBA. The imported raw data is sorted by Mach number and configuration.



Screenshot of raw wind tunnel data in the form of a text file being imported into Excel.



Above: Graph of axial force vs AlphaP with inconsistencies. Below: Graph of axial force vs AlphaP without inconsistencies.



- A macro was written that extracts the measured wind tunnel data necessary for the longitudinal database, merges two runs into a single data set organized by AlphaP (total angle of attack) in ascending order, and produces the equation of a sixth order polynomial using Excel's "LINEST" function from the AlphaP and normal force, axial force, and pitching moment coefficient data. The coefficient data for the cardinal points of AlphaP (±10°, ±8°, ±6°, ±4°, ±2°, ±1°, and 0°) is calculated from the polynomial equation based on the raw wind tunnel data. The original and interpolated coefficient data are plotted in order to check for inconsistencies within the curve fit data as well as the raw wind tunnel data.

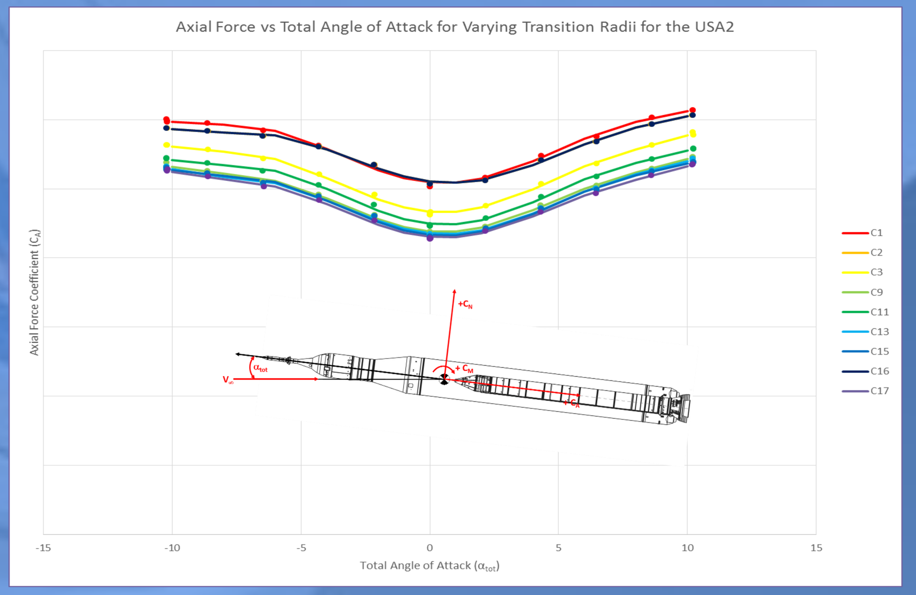
- Develop a macro that creates a coefficient increment from the baseline configuration for each of the USA2 geometries tested. For example, an axial force coefficient increment would be calculated by subtracting the axial force coefficient value for each USA2 configuration tested from the USA2 baseline geometry at each AlphaP and Mach number contained in the database. The result is either a positive (higher) or negative (lower) delta value from the baseline geometry. The resulting increment is used to populate the database.

Table of ΔC values for Configuration 2 at each Mach number tested.

Mach Number	ΔC
Mach 0.8	-0.2536
Mach 0.9	-0.3356
Mach 0.95	-0.3826
Mach 1.0	-0.4995
Mach 1.05	-0.5970
Mach 1.1	-0.6896
Mach 1.15	-0.7160
Mach 1.2	-0.6088
Mach 1.25	-0.5501
Mach 1.3	-0.5314

Conclusions

The SLS USA2 transition geometry, including the transition radius, does have an effect on the longitudinal aerodynamics of the SLS vehicle. This effect has been characterized by the development of the incremental aerodynamic database for the USA2. A straight conical geometry has a lower axial force component (less drag) and would be the most desirable aerodynamically. As the transition radius increases in size, the USA2 becomes blunter and results in a higher drag coefficient. The effect of the transition radius on the overall magnitude of the normal force and pitching moment coefficient appear to be minimal. However, the conical transition does result in a slope change for the pitching moment coefficient. This slope change could have a significant impact on the overall pitching moment characteristic of the integrated launch vehicle.



Graph of Axial Force vs Total Angle of Attack with longitudinal aerodynamic coefficient diagram for the SLS.

Future Work

The incremental aerodynamic database has been developed for several different geometries of the Upper Stage Adapter for the Space Launch System. The increments developed for each geometry will be used to adjust the integrated force and moment aerodynamic database based on the final configuration chosen for the USA2. The database will also be used as a parametric data tool to perform trade studies on varying geometries in order to characterize the effects of changing the transition geometry on the upper stage adapter.

Acknowledgements

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