



Computer Simulation Helps Design Special Boeing 747

Computer simulation is being used to help certify and ensure safety for a specially-modified Boeing 747 that will carry the world's largest airborne telescope in 2001. The National Aeronautics and Space Administration (NASA) and the German space agency (DLR) are working together to create the Stratospheric Observatory for Infrared Astronomy (SOFIA), a 2.5 meter reflecting telescope that will make observations that are impossible for even the largest and highest ground-based telescope. The modifications to the airplane, which include a 10-foot by 10-foot opening in the side of the aft portion of the fuselage, are great enough that it essentially must go through the complete certification process.

Aircraft modifications

Raytheon Systems Company will do the extensive aircraft modification required to build SOFIA. The five-year job of modifying the aircraft for its new scientific role includes installing the telescope and mission control and communications systems. The telescope cavity was placed behind the wings to minimize the structural modifications required to the aircraft. A cabin door opens to reveal a cavity that extends to nearly the entire width of the aircraft. This cavity contains the telescope and is isolated from the rest of the plane by forward pressure bulkheads that maintain pressurization in the rest of the aircraft. Aft-mounting the telescope cavity increased the aircraft integration challenges because it could potentially create strong oscillatory flow in the region of the rear control surfaces that might affect the life and effectiveness of the control surfaces of the aircraft.

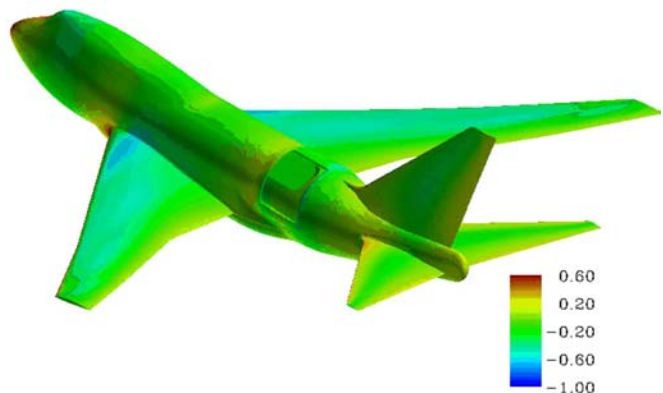
Simulation challenges

The biggest challenge in simulating the aerodynamics of SOFIA was creating a CFD model of the complete aircraft to the level of detail required to accurately model the aircraft in the allocated time. In particular, a high level of detail was required around the rear control surfaces, including the horizontal stabilizer, the elevator and the rudder, in

order to determine the impact of the cavity. While the simulation provides a wide range of information, the most important was the loading on the control surfaces used to help calculate effectiveness, and the impact on the stability and control of the aircraft. This was one of the most complicated gridding problems ever faced by Raytheon Systems Company engineers, particularly because of the level of detail required on the control surfaces and the need to model the control surfaces in many positions.

Modeling process

Raytheon engineers imported an IGES model of the modified aircraft into Gridgen and began defining the grid topology. Engineers used four blocks in the cavity area, one making up the bulk of the cavity, one in the doorway, one just outside the door, and one interfacing the cavity to the rest of the model. Five blocks were used around each of the stabilizers in order to capture critical transients in these areas. The rest of the blocks were larger and defined by natural breaks in the geometry.

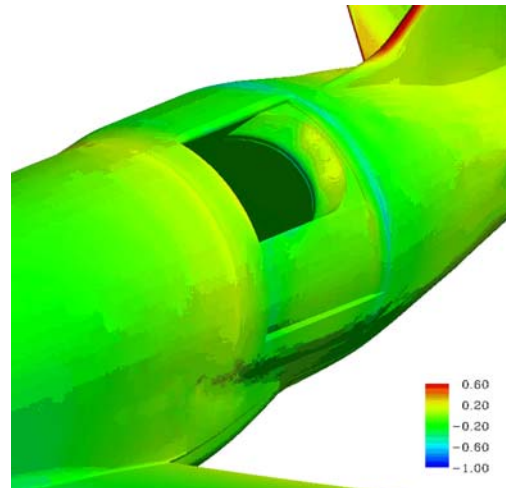


Flow solution resulting from the grids, looking from the left and behind the plane.

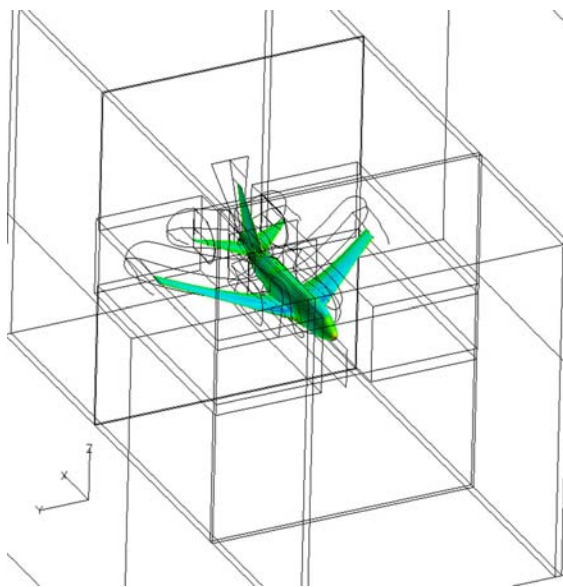
Mesh generation

On this project, engineers used a Gridgen feature that automatically distributes grid points along a connector based on any of a wide range of functions that can be specified by the user. The irregu-

larity of the 747 geometry meant that a conventional multiblock grid would have many areas where the mesh was of poor quality, particularly in transitions between blocks or at the boundaries of the problem domain. These problems would include highly skewed cells and cells with negative and zero volume. With a conventional grid generator, Raytheon engineers would have been forced to modify the grid manually to improve its quality, a process that would have taken weeks. Fortunately, Gridgen allowed the engineers to improve the quality of the mesh automatically by applying elliptic partial differential equation methods. Engineers applied smoothness, clustering and orthogonality controls to improve the mesh. Producing the entire 7-million cell mesh took a small fraction of the time that would have been required using other gridding methods.



Flow solution resulting from the grids, looking from the left wing into the hole.



Grid topology showing the grid boundaries and blocking.

CFD Solution

Solutions were computed using OVERFLOW +MPI, a special version of the CFD code developed by NASA that is designed for parallel processing on a network of workstations, in this case Octanes. OVERFLOW offers users the ability to select from a wide range of proven solvers, smoothers, and turbulence models to solve the three-dimensional (3D) time-dependent Reynolds-Averaged Navier-Stokes equations for fluid motion at moderate Mach numbers. OVERFLOW's typical solution approach is to solve for the fluid motion in the region of interest by determining the flow through a series of connected 3D grids, or zones, that cover the region in a patchwork fashion. The calculation advances in time for all zones until the solution has converged to the user's satisfaction. Typical problem sizes range from small calculations involving about one million points to simulations of an entire aircraft requiring tens of millions of points.

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