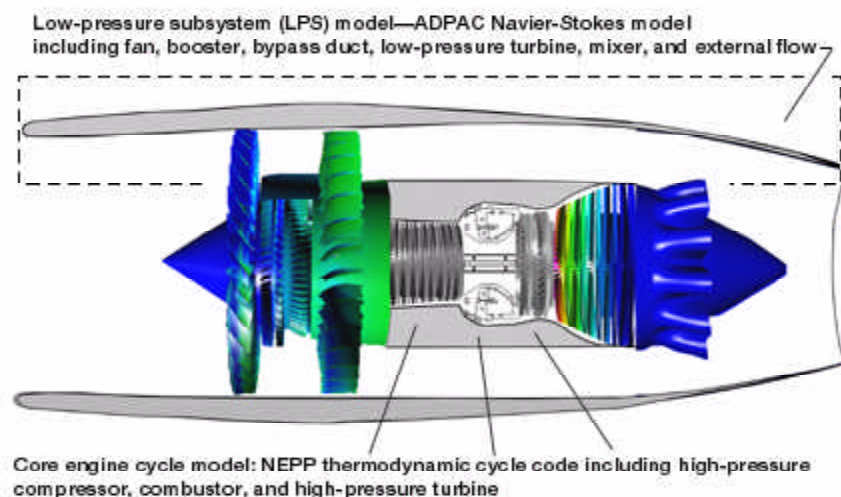# Flow of a Gas Turbine Engine Low-Pressure Subsystem Simulated

The NASA Lewis Research Center is managing a task to numerically simulate overnight, on a parallel computing testbed, the aerodynamic flow in the complete low-pressure subsystem (LPS) of a gas turbine engine. The model solves the three-dimensional Navier-Stokes flow equations through all the components within the LPS, as well as the external flow around the engine nacelle. The LPS modeling task is being performed by Allison Engine Company under the Small Engine Technology contract. The large computer simulation was evaluated on networked computer systems using 8, 16, and 32 processors, with the parallel computing efficiency reaching 75 percent when 16 processors were used.
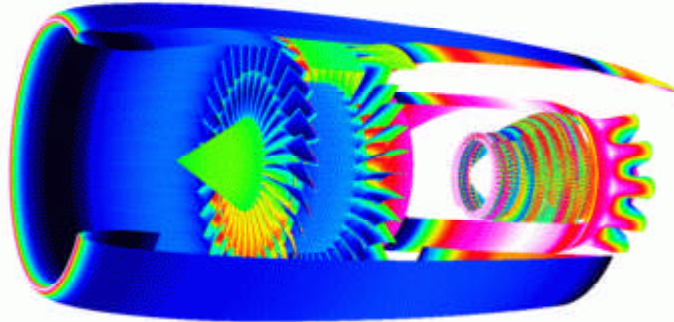

Gas turbine engine geometry and flow simulation of the low-pressure subsystem.

The three-dimensional Navier-Stokes flow code for this LPS simulation is the Advanced Ducted Propeller Analysis Code (ADPAC), and the engine geometry being modeled is the Energy Efficient Engine designed by GE Aircraft Engines. The three-dimensional flow model of the LPS provides a tightly coupled aerodynamic analysis that captures the quasi-steady interaction effects between the components. The high-pressure core engine is simulated with the NASA Engine Performance Program (NEPP) thermodynamic cycle code, and the LPS flow model is linked to the NEPP core engine model by sharing common boundary conditions. Together, the three-dimensional LPS model and the thermodynamic model of the core engine form a hybrid model of the complete engine.

By varying the speed of rotation, researchers were able to use a coarse mesh grid solution to obtain the torque balance between the compression system and the turbine to within 1 percent in a few iterations. Balancing the torque with the ADPAC solution obtained from the coarse mesh enabled the fine mesh numerical solution to be run to full convergence. The large-scale (74-block, 6.7-million-grid-point) simulation of the complete LPS was successfully run on networked workstation clusters on Davinci and Babbage (Ames), on

LACE (Lewis Advanced Cluster Environment), and at Allison. The interaction between components within LPS, as well as between LPS and the core engine were evaluated at various engine operating conditions: that is, the design point at takeoff, and the altitude cruise condition.

Gas turbine engine Navier-Stokes flow simulation.

The hybrid engine model can be used to evaluate the detailed interactions between LPS components while considering the lumped-parameter performance of the core engine. The flow model enables critical engine component interactions to be quantified early in the design phase, reducing the costs associated with numerous engine configuration tests in an engine design program. For capturing detailed propulsion/airframe integration effects on vehicle performance, the model can be coupled to an external aerodynamic simulation of the airframe. The large-scale simulation also helps define the requirements for the computer architecture and simulation environment for the Numerical Propulsion System Simulation (NPSS) project.

Plans in the LPS modeling task include replacing the NEPP engine model with the National Cycle Program (NCP) model, thereby integrating its detailed flow modeling capability into NPSS, which will serve as a "numerical test cell" for turbine engines. The goal of NPSS is to provide a tool that can significantly reduce the design time, risk, and cost associated with designing advanced gas turbine engines.

Lewis contact: Joseph P. Veres, (216) 433-2436, Joseph.P.Veres@grc.nasa.gov
Author: Joseph P. Veres
Headquarters program office: OASTT
Programs/Projects: HPCCP, NPSS, NCP