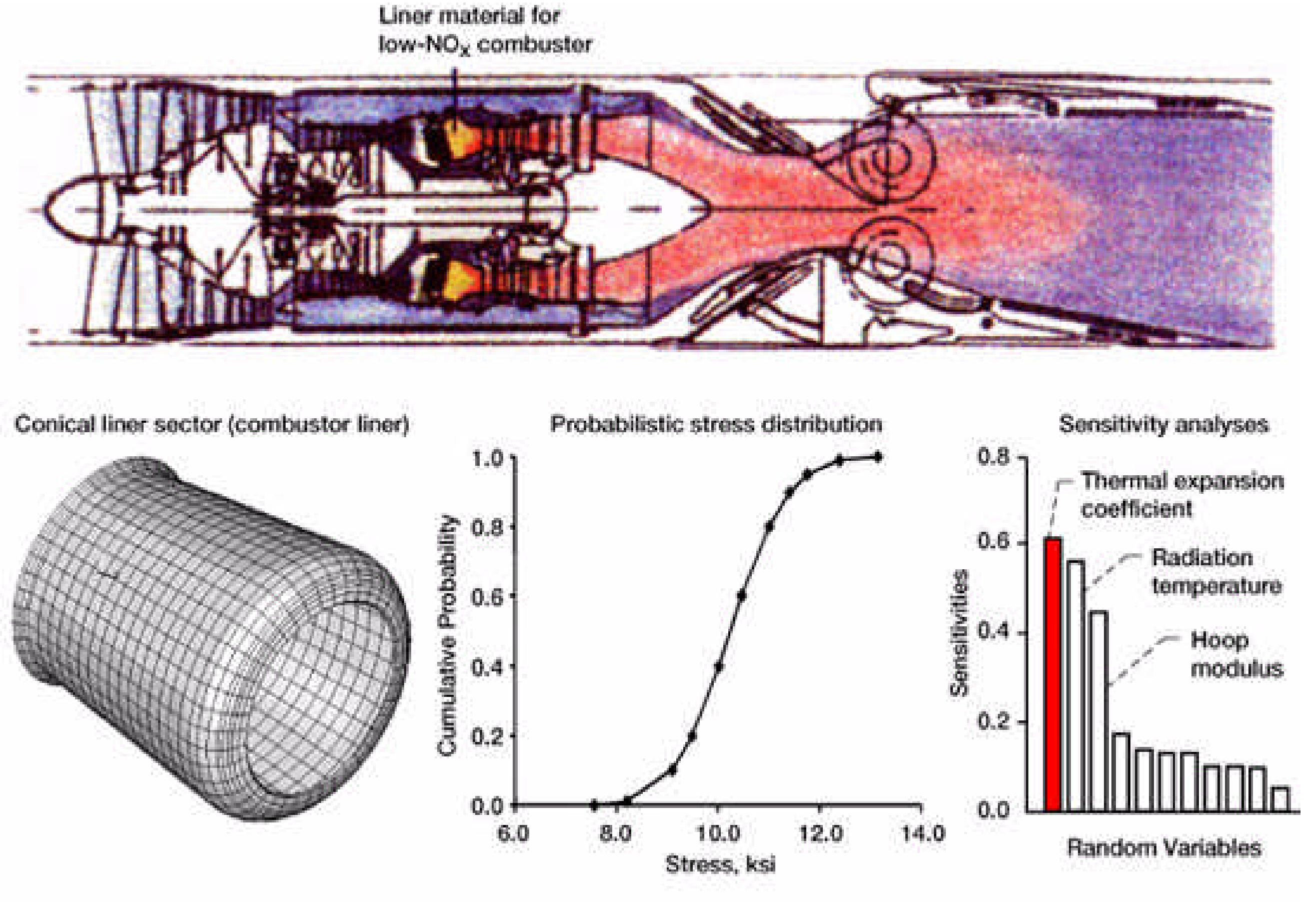
Multidisciplinary Probabilistic Heat Transfer/Structural Analysis Code Developed--NESTEM

High-Speed Civil Transport (HSCT) engine combustor liners are subjected to complex thermal environments and have to endure these for thousands of hours with assured reliability. In the past, several deterministic analyses have been performed, including detailed heat transfer analyses to obtain thermal profiles and deterministic stress analyses to identify critical locations of high stresses. Actual rig tests also have been performed for segments by simulating these loading situations as closely as possible. However, it is well known that many uncertainties exist in loading (primarily thermal loads due to heat transfer), boundary conditions (end fixity unknowns), and material properties (moduli, thermal-expansion coefficients, and conductivities). The present in-house effort at the NASA Lewis Research Center is directed toward accounting for these in a formal way to assess the performance of liner components under complex and uncertain loading conditions as well as subject to other geometry- and material-related uncertainties.



Sample output from NESTEM for a conical ceramic-matrix-composite liner segment.

Under the sponsorship of the Enabling Propulsion Materials (EPM) project, Lewis' Structures and Acoustics Division recently developed a computational capability, NESTEM (see the figures), through a contract to Modern Technologies Corporation. NESTEM is a computer code that combines the heat transfer analysis capability of the EPM backbone computer code CSTEM (Coupled Structural, Thermal and Electro-Magnetic Tailoring) with Lewis' in-house probabilistic structural analysis code NESSUS (Numerical Evaluation of Stochastic Structures Under Stress). The code can now analyze and assess the complex combustor thermal environment with uncertainties, as well as its effects on the overall ceramic matrix composite (CMC) liner response. It enables us to formally assess the uncertainties in loads, material property variations, and geometric imperfections on the overall structural behavior (such as stability, frequencies, and stresses). Typical output of the code is probabilistic stress distributions at the hot spots, probabilistic frequencies, and buckling loads. This information allows designers to make more informed judgments regarding the preliminary design of the liner components without resorting to overly conservative deterministic approaches with ad hoc knockdown factors. The information also permits more accurate calculation of the reliability and life of such components. In addition, the code provides information on the sensitivities of the various uncertainties and ranks them in the order of importance as a byproduct. The accompanying figures show a sample output for a conical ceramic-matrix-composite liner segment.

NESTEM's features include

- Automatic geometry and finite element mesh generation
- Finite element property card generation for arbitrary composite layups
- Uncertainties in heat-transfer-related variables, combustor temperatures, geometry, material properties, and boundary conditions
- Heat transfer and structural analysis in the same run
- Cumulative distribution functions of response, including temperatures, stresses, natural frequencies, buckling loads, and displacements
- Sensitivities of variables with uncertainties at various probability levels

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