# FACT SHEET

## TITLE: <u>Development of NDE Technology for Oxide-Based Ceramic Composite Materials</u>

## Project Objective:

This project will develop the necessary non-destructive evaluation (NDE) methods for assuring reliable usage of oxide-based ceramic composite materials in advanced , low-emission, high efficiency gas turbines. Components made from oxide-based composites will be studied with and without high-temperature environmental barrier coatings (EBCs). The NDE measured defect state (induced artificially or by typical usage conditions) will be correlated with results from traditional destructive characterization assessments. This NDE work also addresses the critical issue of estimating remaining useful life of installed components based on internal damage assessments and tested damage accumulation models.

## Background/Relevancy

Oxide-based ceramic composites show promise in providing longer life at lower costs when used as components in hot sections of gas turbines. These oxide-based materials have better high temperature performance than metallic alloys and have better oxidation resistance than silicon-based composites. However, to avoid issues such as high temperature creep and thermal shock, it is necessary to utilize a high temperature coating between the hot gas path and the oxide composite material. These coatings act as both an environmental barrier and a thermal barrier. During development of these materials and processing methods, it is necessary to have NDE technologies available that can assess component quality at various points in the production path. Further, in order to reduce risk to the engines that utilize these components, it is necessary to have NDE technologies that assure quality of the components prior to insertion in the engine. NDE technologies, especially those that are non-contact and can be performed at a distance or in tight spaces, can be used to ascertain the structural integrity of the components during machine downtimes. Use of NDE data together with appropriate analytical models, hold the promise of estimating remaining useful life of these components while in service, thus allowing informed replace/reuse maintenance decisions.

## Period of Performance:

8/01 to 8/04

## Project Summary:

The work of this project, directed towards developing non-contact, nondestructive characterization technologies, is a cooperative effort with Siemens-Westinghouse Power Corporation of Orlando, FL, and Composite Optics, Inc of San Diego, CA. Composite Optics, Inc is producing the full scale engine test components as well as developing various special test components with well-defined features such as delaminations and density variations that can be used as test articles for detection sensitivity by the non-contact, nondestructive methods under development. Argonne is developing several non-contact, nondestructive technologies including thermal imaging using steady-state heating, one-sided air-coupled imaging ultrasonics, and acousto-ultrasonic materials response measurements using guided plate waves. In the work of this project, directed towards estimating remaining useful lifetimes of the components, Argonne is building on their previous work directed towards silicon-based composites. Elastic modulus determination from data generated with acousto-ultrasonics methods is coupled with a damage parameter model to estimate remaining useful life when the component is subjected to cyclic fatigue.

## Project Participants:

Argonne National Laboratory (William Ellingson, PI)
Collaborators (in-kind support, sample sourcing, in-service testing):
Siemens Westinghouse Power Corporation

Composite Optics
Solar Turbines

## Project Costs
DOE $835k

## Major Accomplishments
· Thermal imaging tests were completed on oxide-based composite test samples with and without the high temperature protective ceramic coatings. Methods using steady-state heating were developed. The thermal imaging technique was applied to several actual coated combustor liners as well as the specially made test samples. The imaging was able to detect suspected materials degradation regions in the liners and correlate them with materials processing events and qualify the defects as sub-critical. The liner is now in a combustion unit and is experiencing in-service testing.
· Air-Coupled and water-coupled ultrasonic methods were explored for detection sensitivity to known delaminations in test samples. Air-Coupled methods are sensitive down to a 6mm defect size limit which is below the presently understood critical size limit established for allowed service use.
· Cyclic fatigue testing was conducted and initial nondestructive data obtained using an Argonne-developed acousto-ultrasound system. The tests measure material elastic response properties related to damage accumulation.

## Future Accomplishments (next 9 months)
·The detection sensitivity of various non-contact, nondestructive techniques will be explored relative to detection of various known damage levels. This will fully establish the spatial resolution attainable with the NDE methods.
·The methods used for life-time prediction modeling will be further explored to establish the proper material degradation model and the suitability of the measured elastic wave parameters.
·The material thermal response will be explored using pulsed laser heating and thermal imaging. This will be added to NDE elastic response data and will be coupled to existing damage models to establish if the same logic can be applied to oxide-based composites that has been applied to carbide systems.
·A pre-qualified combustion liner will be imaged after completion of a long term combustion test to determine if defects have increased and to correlate NDE detected damage with destructive evaluation.