

# Why MDS

MDS provides unmatched combination of practicality, rigor, validation and versatility:

## Practicality

- MDS is equipped with a systematic model reduction technology that reduces complex unit cells having hundreds of thousands of finite elements to a manageable number of deformation modes and state variables.
- MDS is equipped with an extensible library of parametric unit cell models generated automatically using MDS built-in CAD and meshing tools.

## Mathematical rigor

- MDS is free of scale separation and provides mesh insensitive results. The characteristic material length scale is identified based on experimental data.
- MDS is equipped with stochastic multiscale capabilities that translate geometrical and material uncertainties into the component level uncertainties.

## Validation

- MDS is integrated with an experimental material data base and a multi-step optimization engine that identifies model parameters having high degree of uncertainty (such as content of voids, micro-cracks, interface/interphase properties).

## Versatility

- Advanced features include: microstructural optimization, multiscale fatigue and multiphysics analyses, generation of A- & B-basis allowables with minimum testing and without compromising on accuracy.

# About MDS

*MDS, LLC* was founded in 2008 by Prof. Fish and associates. The main software product, Multiscale Design System (MDS) is based on more than 30 years of pioneering research in multiscale science and engineering by Prof. Fish.

*Prof. Fish, the Carleton Chaired Professor at Columbia University*, is an author of more than 170 journal articles on various aspects of multiscale science and engineering and several books including the first multiscale textbook entitled "Practical Multiscale" published by Wiley in 2013.

Since its inception in 2008, MDS, LLC won numerous SBIR/STTR Phase I and Phase II awards on environmental degradation of high temperature polymer and ceramic matrix composites subjected to thermal oxidation, fatigue, moisture ingress and mechanical loading.

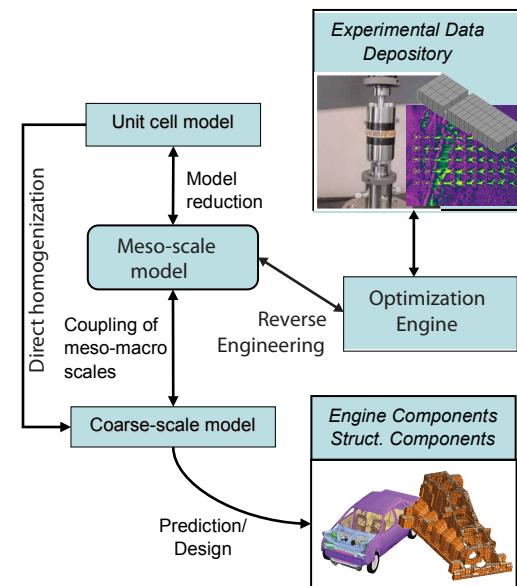
## How our Major Customers are utilizing MDS:

- Rolls-Royce Aerospace for *life prediction of ceramic matrix composites* where it is used as a plug-in to ABAQUS Standard;
- Lockheed-Martin and Northrop Grumman for *high temperature polymer matrix composites*;
- General Motors for *crash prediction of composite cars* where it is used as a plug-in to LS-DYNA and ABAQUS Explicit;
- ARL and NRL for *analysis of complex multiphysics problems at multiple scales*.

# What is MDS

MDS delivers a breakthrough technology for seamless integration of modeling, simulation, testing, uncertainty quantification and optimization of composite materials and structures at multiple spatial and temporal scales.

## Flowchart of Multiscale Design Process in MDS

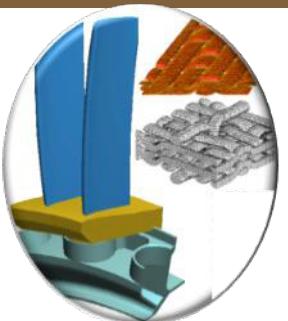




### **MDS-C**

#### *Multiscale Design System for Continuum*

MDS-C is based on the micromechanical approach that possesses minimal number of internal variables representing inelastic deformation of microphases and their interfaces. It resolves microscale fields at a computational cost comparable to the macromechanical modeling. MDS-C precomputes material database, such as transformation influence functions, in the preprocessing stage prior to nonlinear analysis, which is subsequently reused in the nonlinear analysis. MDS-C has been validated on more than 50 benchmark problems at a coupon and component levels for various composites.

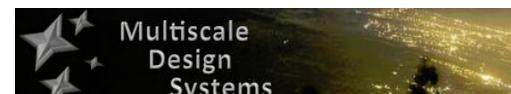
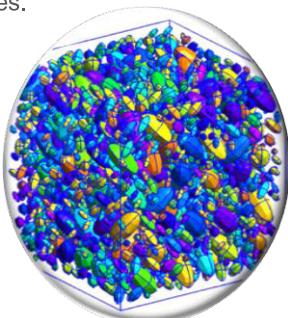


### **MDS-UQ**

#### *Multiscale Stochastic Design System*

MDS-UQ provides stochastic forward and inverse capabilities.

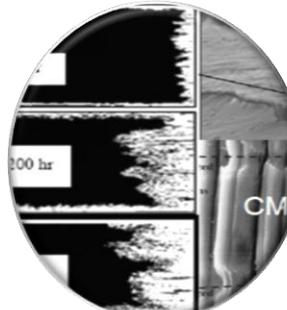
MDS-UQ stochastic forward process computes the pdf of macroscale quantities of interest and allowables based on the pdf of the microscale geometry and constitutive equations. MDS-UQ stochastic inverse process reverse engineers the pdf of microscale properties based on the pdf of the experimental data at a coupon level.



### **MDS-MP**

#### *Multiscale Multiphysics Design System*

MDS-MP is based on the unified coupled multiscale mechano-diffusion-reaction model of environmental degradation of polymer and ceramic matrix composites. MDS-MP couples multiple physical processes at multiple scales, including oxygen and/or moisture diffusion, reaction and deformation. The salient feature of MDS-MP is its computational efficiency accomplished through model reduction for multiple physical processes. MDS-MP has been validated for PMR-15 and MVK-14 reinforced carbon fiber composite and Melt Infiltrated CMC-NASA N24A material system.



### **MDS-FT**

#### *Multiscale Fatigue Design System*

MDS-FT is based on the two-scale asymptotic homogenization approach

in time and reduced order homogenization in space that can be effectively applied to any material architecture and any constitutive equations of microphases. MDS-FT has been validated for chemical vapor Infiltrated (CVI), melt Infiltrated (MI) ceramic composites, and PMR-15 and MVK-14 reinforced carbon fiber composites.



### **Contact**

Email: [info@multiscale.biz](mailto:info@multiscale.biz)

Web: [www.multiscale.biz](http://www.multiscale.biz)

Phone: +1-518-496-0173

Fax: +1-917-677-2112

Address: Multiscale Design Systems, LLC  
280 Park Ave South, Suite 22M  
New York, NY 10010, USA

### **Services**

We customize various MDS products to fit your needs and integrate with your existing software. If you need any features or integration with commercial software packages currently not offered by MDS, our development staff can assist in providing the solutions that work right for you. To request new features and/or services email your request to [info@multiscale.biz](mailto:info@multiscale.biz)

We provide a one-day on-site training service with our software products to help you successfully use MDS tools.

We provide free webinars. Send an e-mail to [info@multiscale.biz](mailto:info@multiscale.biz) to schedule a new webinar.

### **MDS License**

MDS has three products: MDS-Lite (free – multiscale linear analysis), MDS-Standard (MDS-C only), MDS-Professional (MDS-C, MDS-UQ, MDS-MP, MDS-FT).

All products are licensed on annual per-machine basis. For various licensing options contact [sales@multiscale.biz](mailto:sales@multiscale.biz).

We also offer a full-functionality academic edition, MDS-Academic, at reduced rate.



[www.multiscale.biz](http://www.multiscale.biz)