"Materials Prognosis: Integrating Damage-State Awareness and Mechanism-Based Prediction"

San Diego, California, USA, March 2-6, 2003

In conjunction with the 132nd Annual Meeting & Exhibition of TMS

Sponsored by: Structural Materials Division

Program Organizers: James M. Larsen: Air Force Research Laboratory - 937-255-1357
Leo Christodoulou: Defense Advanced Research Agency - 703-696-2374
J. William Hardman: Naval Air Systems Command - 301-757-0508
Andrew Hess: Naval Air Systems Command - 703-604-6033, ext. 223
J. Wayne Jones: University of Michigan - 734-764-7503
Stephan M. Russ: Air Force Research Laboratory - 937-255-1356

Scope: This symposium is intended highlight scientific tools and approaches for development of a comprehensive damage prognosis technology for materials. The objective of such a prognosis capability is to enable continual assessment and prediction of the current and future health of materials in a complex mechanical system or subsystem, such as a turbine engine, helicopter gearbox, or aircraft. The ultimate goal is the development of quantitative models that relate a system's-level structural response to material's-level microstructural events.

Areas of emphasis include:
(1) methods for in situ interrogation of the damage state of a material, such as that from fatigue and/or creep,
(2) physically-based models of the formation and growth of material damage under realistic loading, and
(3) coupled state-awareness and life models, including probabilistic and uncertainty approaches. The symposium is expected to attract participants from diverse but interdependent disciplines including materials science, mechanical engineering, physics, and diagnostic state-awareness engineering

Session Agenda

Materials Prognosis: Integrating Damage-State Awareness and Mechanism-Based Prediction: Prognosis Opportunities & Applications

Sponsored by: Structural Materials Division,

Program Organizers: James M. Larsen, US Air Force, Air Force Research Laboratory, Materials and Manufacturing Directorate, Wright-Patterson AFB, OH 45433-7817 USA; Leo Christodoulou, Defense Advanced Research Agency, Arlington, VA 22203-1714 USA; William J. Hardman, Naval Air Systems Command, Propulsion and Power Directorate (AIR 4.4.2), Patuxent River, MD 20670-1534 USA; Andrew J. Hess, Naval Air Systems Command, Propulsion and Power Directorate, Patuxent River, MD 20670-1534 USA; J. Wayne Jones, University of Michigan, College of Engineering, Department of Materials, Science and Engineering, Ann Arbor, MI 48109 USA; Stephan M. Russ, Air Force Research Laboratory, Materials and Manufacturing Directorate, AFRL/MLLN, Wright-Patterson Air Force Base, OH 45433-7817 USA

Monday AM **Room: 16A**
March 3, 2003 **Location: San Diego Convention Center**

Session Chairs: James M. Larsen, US Air Force, AF Rsrch. Lab., Matls. & Mfg. Direct., WPAFB, OH 45433-7817 USA; Leo Christodoulou, Defense Advanced Research Agency, Arlington, VA 22203-1714 USA

8:30 AM Invited
Materials Prognosis as a Tool to Assure Readiness and Maximize the Utilization Potential of Complex Mechanical Systems: *Leo Christodoulou*[2]; James M. Larsen[1]; [1]Air Force Materials Laboratory, AFRL/MLLMN, 2230 Tenth St., Ste. 1, WPAFB, OH 45433-7817 USA; [2]Defense Advanced Research Projects Agency, DARPA/DSO, 3701 N. Fairfax Dr., Arlington, VA 22203-1714 USA

9:00 AM Invited
A Prognostic Development Strategy and the Way Forward: *Andrew J. Hess*[1]; [1]NAVAIR, AIR 4.4.2, B106, Unit 4, 22195 Elmer Rd., Patuxent River, MD 20670 USA

9:30 AM Invited
Turbine Engine Health Managing Future Direction: Theodore George Fecke[1]; [1]Air Force Research Laboratory, AFRL-PRTC, 1950 Fifth St., WPAFB, OH 45433 USA

10:00 AM Break

10:30 AM Invited
The Role of State Awareness Sensors for Advanced Prognostic Systems: *Jerrol W. Littles*[1]; Bradford A. Cowles[1]; Richard A. Holmes[1]; Robert B. Berkley[1]; [1]Pratt & Whitney, E. Hartford, CT 06108 USA

11:00 AM Invited
Structural Health Monitoring of Aerospace Vehicles Using Advanced Signal Analysis Techniques: *Mark M. Derriso*[1];
[1]Air Force Research Laboratory, Air Vehicles Direct., 2790 D. St., WPAFB, OH 45433 USA

11:30 AM Invited
A Coupled Approach to Damage Prognosis: *Chuck Farrar*[1]; [1]Los Alamos National Laboratory, Eng. Sci. & Applic., MS T-006, Los Alamos, NM 87545 USA

Monday PM **Room: 16A**
March 3, 2003 **Location: San Diego Convention Center**

Session Chairs: Theodore G. Fecke, Air Force Research Laboratory, AFRL/PRTC, WPAFB, OH 45433-7251 USA; Michael J. Caton, US Air Force, AFRL/MLLMN, WPAFB, OH 45433-7817 USA

2:00 PM Invited
Materials Aging, Prognostics, and Life Cycle Engineering and Management: *Robert P. Wei*[1]; D. Gary Harlow[1]; [1]Lehigh University, Mechl. Eng. & Mech., 327 Sinclair Lab., 7 Asa Dr., Bethlehem, PA 18015 USA

2:30 PM Invited
Fatigue Prognostics Using Microstructurally-Based Total Life Models: *Robert G. Tryon*[1]; Amimesh Dey[1]; [1]VEXTEC, 116 Wilson Pike, Ste. 230, Brentwood, TN 37027 USA

2:55 PM Invited
Physically-Based Life-Prediction Models for Applications in Engine Integrity Prognostics: *Kwai S. Chan*[1]; [1]Southwest Research Institute, 6220 Culebra Rd., San Antonio, TX 78238 USA

3:20 PM Break

3:50 PM Invited
The Role of Statistical Variability in Fatigue Crack Growth Rates in Materials Prognosis: *Michael J. Caton*[1]; Andrew H. Rosenberger[1]; James M. Larsen[1]; [1]US Air Force Research Laboratory, Matls. & Mfg. Direct., AFRL/MLLMN, WPAFB, OH 45433-7817 USA

4:15 PM Invited
The Use of Ultrasonic Fatigue in the Modeling of Very Long Fatigue Life: *J. Wayne Jones*[1]; Michael J. Caton[2]; [1]University of Michigan, Matls. Sci. & Eng., 2018 H. H. Dow, 2300 Hayward Ave., Ann Arbor, MI 48109 USA; [2]Air Force Research Laboratory, Matls. & Mfg. Direct, AFRL/MLLMN, WPAFB, OH 45433-7817 USA

4:40 PM
Fatigue Behavior of Al-Si-Cu Aluminum Castings: *Qigui Wang*[1]; Peggy Jones[1]; [1]General Motors Corporation, CDVC-Powertrain, 1629 N. Washington Ave., Saginaw, MI 48605 USA

Tuesday AM **Room: 16A**
March 4, 2003 **Location: San Diego Convention Center**

Session Chairs: Stephan M. Russ, Air Force Research Laboratory, Matls. & Mfg. Direct., WPAFB, OH 45433-7817 USA; Michael L. Dent, Air Force Research Laboratory - Anteon Corp., Matls. & Mfg. Direct., WPAFB, OH 45433-7817 USA

8:30 AM Invited
Overview of Technologies to Support Risk-Based Prognostic Decision System: *Thomas A. Cruse*[1]; [1]Consultant, 398 Shadow Pl., Pagosa Springs, CO 81147 USA

9:00 AM Invited
Enhanced Prognosis Through Probabilistic Damage Assessment: *Stephen J. Hudak*[1]; Michael P. Enright[1]; Harry R. Millwater[2]; R. Craig McClung[1]; [1]Southwest Research Institute, Matls. Eng. Dept., 6220 Culebra Rd., San Antonio, TX 78238-5166 USA; [2]University of Texas at San Antonio, TX, USA

9:25 AM Invited
Damage Indicators for Advanced Life Prediction Systems: *Eva L. Suarez*[1]; Yoshika Omori[1]; Michael J. Duffy[1]; [1]Pratt & Whitney, Fatigue & Fracture Mech., 400 Main St., MS 163-07, E. Hartford, CT 06108 USA

9:50 AM Break

10:20 AM Invited
eSTORM: Enhanced Self Tuning On-Board Real-Time Engine Model: *Thomas Brotherton*[1]; Al Volponi[2]; Rob Luppold[3]; Donald L. Simon[4]; [1]Intelligent Automation Corporation, 13029 Danielson St., Ste. 200, Poway, CA 92064 USA; [2]Pratt & Whitney, E. Hartford, CT, USA; [3]Luppold & Associates, 164 N. Water St., W. Newton, PA 15089 USA; [4]US Army Research Laboratory, NASA Glenn, Cleveland, OH, USA

10:45 AM Invited
Vibration-Based Crack Detection in Rotating Engine Components: *Héctor M. Rodríguez*[1]; Huageng Luo[1]; Dennis M. Corbly[2]; [1]GE, Global Rsrch., 1 Research Cir., K1-2A72, Niskayuna, NY 12309 USA; [2]GE, Aircraft Engines, 1 Neumann Way, A413, Cincinnati, OH 45215 USA

11:10 AM Invited
USN Rotor Spin Facility Experience with Disk Crack Detection Sensing Technology: *Greg C. Muschlitz*[1]; [1]NAVAIR, AIR 4.4.7.1, B106, Unit 4, 22195 Elmer Rd., Patuxent River, MD 20670-1534 USA

11:35 AM Invited
Updating Turbomachinery Fatigue Life Remaining by Use of Blade-Tip Sensors: *Andreas H. von Flotow*[1]; [1]Hood Technology Corporation, 1750 Country Club Rd., Hood River, OR 97031 USA

Tuesday PM **Room: 16A**
March 4, 2003 **Location: San Diego Convention Center**

Session Chairs: William J. Hardman, Naval Air Systems Command, Propulsion & Power Direct, Patuxent River, MD 20670-1534 USA; Reji John, Air Force Research Laboratory, AFRL/MLLMN, WPAFB, OH 45433-7817 USA

2:00 PM
Nonlinear Acoustics and X-Ray Diffraction for Evaluation of the Fatigue Damage-State in Ti-6Al-4V: *Shamachary Sathish*[1]; Jerome Frouin[1]; [1]University of Dayton Research Institute, 300 College Park, Dayton, OH 45469-0127 USA

2:30 PM Invited
Material Characterization and Life Prediction for Critical Components Through Application of Photon Induced Positron Annihilation (PIPA): *Douglas Akers*[1]; [1]Positron Systems, Inc., 6151 N. Discovery Way, Boise, ID 83713 USA

2:55 PM
Scattered Light Scanning for Fatigue Damage Precursor Detection on Turbine Components: *James C. Earthman*[1]; [1]University of California-Irvine, Chem. Eng. & Matl. Sci., Eng. Tower 916, Irvine, CA 92697-2575 USA

3:20 PM Break

3:50 PM
Nondestructively Estimated Damage Degradation in Ceramic Matrix Composites: *Chris Deemer*[1]; Benjamin J. Wheeler[1]; William A. Ellingson[1]; [1]Argonne National Laboratory, Energy Tech. Div., 9700 S. Cass Ave., Argonne, IL 60439 USA

4:15 PM
Ball Indentation for Nondestructive Monitoring of Thermal Aging of Cast Stainless-Steel (CF-8) and Alloy 625: *K. L. Murty*[1]; M. D. Mathew[2]; [1]North Carolina State University, 2500 Stinson Dr., PO Box 7909, Raleigh, NC 27695-7909 USA; [2]Indira Gandhi Center for Atomic Research, Kalpakkam 603102 India

4:40 PM
Piezoelectric In-Situ Transmission Electron Microscopy Observations of Fatigue Damage Accumulation in Constrained Metallic Thin Films: X. Tan[1]; P. Liu[1]; *J. K. Shang*[1]; [1]University of Illinois at Urbana-Champaign, Dept. of Matls. Sci. & Eng., 1304 W. Green St., Urbana, IL 61801 USA

5:05 PM
Mechanism-Based Models for the Prediction of Fatigue in Si MEMS Structures: Seyed Allameh[1]; M. Huang[1]; P. Shrotriya[2]; Y. Cao[1]; Z. Suo[1]; *W. O. Soboyejo*[1]; [1]Princeton University, Princeton Matls. Inst., D404 E. Quad., Princeton, NJ 08544 USA; [2]Brown University, Div. of Eng., Providence, RI 02912 USA

Wednesday AM Room: 16A
March 5, 2003 Location: San Diego Convention Center

Session Chairs: Jay R. Jira, US Air Force, AF Rsrch. Lab., Matls. & Mfg. Direct., WPAFB, OH 45433-7817 USA; Robert A. Brockman, University of Dayton Research Institute, Dayton, OH 45469-0110 USA

8:30 AM
A USN Strategy for Mechanical and Propulsion Systems Prognostics with Demonstration Results: *William J. Hardman*[1]; [1]NAVAIR, AIR 4.4.2, B106, Unit 4, 22195 Elmer Rd., Patuxent River, MD 20670-1534 USA

9:00 AM Invited
Calibration of Failure Mechanism-Based Prognosis with Vibratory State Awareness Applied to the H-60 Gearbox: *Gregory J. Kacprzynski*[1]; Avinash Sarlaskar[1]; Andrew J. Hess[2]; [1]Impact Technologies, LLC, 125 Tech Park Dr., Rochester, NY 14623 USA; [2]Naval Air Systems Command, 22195 Elmer Rd., Patuxent River, MD 20670 USA

9:25 AM Invited
Modeling of a Gear with EDM Crack: *Alan C. Leung*[1]; Virginia G. DeGiorgi[2]; [1]Nova Research (Naval Research Laboratory), Multifunctl. Matls.-6353, 1900 Elkin St., Ste. 230, Alexandria, VA 22308 USA; [2]Naval Research Laboratory, Multifunctl. Matls.-6353, 4555 Overlook Ave. SW, Washington, DC 20375 USA

9:50 AM Break

10:20 AM Invited
Integrating Structural Analysis and Experimental Methods: *Robert A. Brockman*[1]; [1]University of Dayton Research Institute, 300 College Park Ave., MS 0110, Dayton, OH 45469-0110 USA

10:45 AM Invited
Prediction of Elevated Temperature Crack Growth in Spin Pit Tests: *Robert H. Van Stone*[1]; [1]GE, Aircraft Engines, 1 Neumann Way, MD K105, Cincinnati, OH 45215 USA

11:10 AM Invited
Materials Prognosis for Legacy Engines: *Bryon J. Wicks*[1]; [1]Department of Defense, DSTO-PSL-AVD, Box 4331, GPO, Melbourne, Victoria 3001 Australia

Wednesday PM Room: 16A
March 5, 2003 Location: San Diego Convention Center

Session Chairs: J. Wayne Jones, University of Michigan, Col. of Eng. Dept. of Matls. Sci. & Eng., Ann Arbor, MI 48109 USA; David Alan Johnson, Air Force Research Laboratory, WPAFB, OH 45433-7817 USA

2:00 PM
Micron- and Nano-Scale Mechanical Testing for Model Parameterization: *Dennis M. Dimiduk*[1]; Michael Uchic[1]; Triplicane A. Parthasarathy[2]; Yoon-Suck Choi[2]; [1]Air Force Research Laboratory, Matls. & Mfg. Direct., AFRL/MLLM, WPAFB, OH 45432 USA; [2]UES, Inc., Dayton, OH 45432 USA

2:30 PM Invited
Modeling the Physics of Microstructure Failure in a Nickel Alloy: *Donald A. Shockey*[1]; Jeffrey W. Simons[2]; Brian D. Peterson[2]; Takao Kobayashi[2]; [1]SRI International, Ctr. for Fracture Physics, 333 Ravenswood Ave., Menlo Park, CA 94025 USA

2:55 PM Invited
Enhanced Damage-State Awareness Through Full-Field Measurement Techniques: *David Alan Johnson*[1]; [1]Air Force Research Laboratory, AFRL/MLLMN, Bldg. 655, Ste. 1, 2230 Tenth St., WPAFB, OH 45433-7817 USA

3:20 PM Break

3:50 PM
Mechanisms of Elevated Temperature Fatigue Crack Growth of Ti-6Al-4V: Tarun Goswami[1]; David S. Gelles[2]; Russell H. Jones[2]; [1]Arkansas Tech University, Mechl. Eng., Russellville, AR 72801 USA; [2]Pacific Northwest National Laboratory, Matls. Sci., PO Box 999, Richland, WA 99352 USA

4:15 PM
Integrating Damage State: From Micro-Mechanism to Macroscopic Behavior: *Xijia Wu*[1]; [1]National Research Council of Canada, Inst. for Aeros. Rsrch., M-13, 1200 Montreal Rd., Ottawa, Ontario K1A 0R6 Canada

4:40 PM Invited
Creep Life Prediction Using a Multiple-Damage State Variable Model: Application to Aluminum Alloy 2650: Alex Djakovic[1]; Hector Basoalto[1]; *Brian F. Dyson*[1]; Malcolm McLean[1]; [1]Imperial College of Science, Technology and Medicine, Matls., Prince Consort Rd., London SW7 2BP UK

5:05 PM Invited
Crystal Rotations During Multiaxial Creep in Single Crystal Superalloys: Characterization and Modeling: Mamoud G. Ardakani[1]; Hector Basoalto[1]; Barbara A. Shollock[1]; *Malcolm McLean*[1]; [1]Imperial College of Science, Technology and Medicine, Matls., Prince Consort Rd., London SW7 2BP UK